HERD DURATION, SIZE, AND AGE COMPOSITION IN RELATION TO BRITISH PEDIGREE CATTLE BREEDING, WITH PARTICULAR REFERENCE TO THE AYRSHIRE AND JERSEY BREEDS.

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Thesis presented by

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C O N T E N T S.

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GENERAL INTRODUCTION.

The investigations reported in the following pages were undertaken with the object of adding to our knowledge of the populations of British pedigree cattle. Until a reasonably complete account has been given of the structure, organization and biology of these populations, it will be difficult to make a just appraisal of present methods of breeding better livestock, or to design efficient measures for improving the rate of progress. As a result of recent developments in the field of population genetics, the possibility of guiding the evolution of domestic animals has been greatly extended, and it is hoped that the data now presented will prove useful in exploiting this opportunity.

Falling naturally, as they do, into four groups, the problems studied are described in four separate but related accounts. These deal with (a) the ages of cows and bulls; (b) the duration of herds; (c) the size of herds; and (d) the relation between herd size, milk recording and tuberculin testing. The account of herd size, which was enlarged by data provided by Dr. H. P. Donald, has already been published in the Journal of Agricultural Science.

This opportunity must be taken of expressing my thanks to Dr. A. W. Greenwood for extending to me the hospitality of the Institute of Animal Genetics, Edinburgh, and for making its facilities available for my investigations. I am especially indebted to Dr. H. P. Donald for his valuable advice and guidance throughout this work.

PART I.

THE AGE DISTRIBUTIONS OF PEDIGREE AYRSHIRE AND JERSEY COWS AND BULLS.

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C O N T E N T S.

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1. Introduction.

The average age and length of productive life of dairy cattle has been much studied in the past from various points of view. In 1928 the West Sussex Milk Recording Society (quoted by McCandlish, 1930) published data indicating a replacement rate of 32.2% per year. As McCandlish pointed out, however, the wastage included cows disposed of but continuing their productive life elsewhere. The same difficulty was encountered by McCandlish himself, and later workers (Wright, 1933; N.I.R.D., 1933; Pettit, 1940), but not overcome owing to the lack of data on the fate of cows sold for further milking. The various estimates of the length of productive life of the dairy cow in Britain have been summarised in the following Table.

TABLE 1./

TABLE 1.

Estimates of the length of productive life of dairy cows in Britain.

Author.	Productive life years.	Remarks.
West Sussex M.R.S. 1928	2.25	Milk records; probably too low.
Roberts .. 1929.	3.5	6th and later lactations combined and counted as 6th only.
Wyllie .. 1929.	3.6	
Wright .. 1933.	3.6	Average age assumed to be the same as average productive life plus average age at first calving.
N.I.R.D. .. 1933.	3.25	Based on crude replacement rate.
Pettit .. 1940.	3.4	Based on replacement rate adjusted for increasing numbers.
Sanders .. 1939	3.6	Quoted by Pettit (1940).

Each of the estimates in this table are for average productive herd life in contrast to average total productive life. There is general agreement that a dairy cow spends about 3.5 years in a herd which amounts to about three calves and three lactations. Results of similar investigations in other countries indicate that the conditions of dairying cause some variation in the length of life and wastage rates. Engeler (1933) working with Brown Swiss cows found that the average lifetime to be 8.5 years. German workers (reported in the Berl. u. Munch. Tier. Wochenschrift, 1941) found the average age of Angeln Herdbook cows to be 7½ years, but on many farms the average was only 5-6 years. In the U.S.A. Baltzer (1940) found that in Michigan 24% of the cows were removed from herds each year. These figures may be compared with those of Williams (1943), who found a wastage rate of 33.6% in Welsh herds, and of Chitty (1943) who found that in a group of 43 English herds 446 cows were disposed of out of a total of 1679.

Bridges (1943) showed clearly that the estimates of wastage and replacement rate depend largely on the type of dairying practised. In areas characterized by seasonal milk production and by high cow density with little or no rearing of young stock, the replacement rate may be as high as 47% per year, while level producing or breeding and rearing areas may have comparatively low rates like 27%. The actual value obtained/

obtained will clearly depend on the area from which the data are taken and the distribution of the various types of dairy farming in it. If, however, the published data refer mainly to level producing and breeding areas, and if, as Kay and McCandlish (1929) maintain, dairy cows in Britain do not reach their mature level of production until their 7th or later year of age, it is clear that these figures indicate the existence of serious economic and disease problems. From the genetical point of view, however, such data which are mainly based on large combined samples of milk records or economic surveys, and data on average ages for pedigree cattle as reported by Buchanan Smith and Robison (1931) leave something to be desired. Firstly, as Pettit has pointed out, it may not be correct to assume that average age is a sound guide to average productive life; secondly, the distribut::ion of ages is necessary in order to calculate the proportions of animals giving the various amounts of evidence of their breeding value either in terms of progeny or lactation yields; and thirdly, the use of such averages may obscure wide differences induced by locality or management.

The object of the present study is to re-examine the question of the ages of dairy cattle with these objections in mind; and to consider the age distribution of two breeds of pedigree dairy cattle in relation to the problem of securing adequate performance/

performance data on bulls and cows for selective breeding. The work is therefore primarily an extension of that begun by Smith and Robison (1931) who considered only the ages of pedigree cattle in contrast to that of other workers who did not distinguish between pedigree and non-pedigree herds.

2. Material and Methods.

The material for this study came from the herdbooks of the Ayrshire and Jersey breeds. A random sample of the females registered in the 1940 Ayrshire herdbook was obtained by the usual methods of selecting entries at fixed points on each page. In respect of each entry the date of birth was noted, then the dates of birth and other details of the two parents looked up in previous volumes. Owing to the large number of entries a sufficiently large sample of Ayrshires was yielded by taking one entry per page, but with Jerseys it was necessary to take two entries per page. Details of the samples are given in Table 2.

TABLE 2.

Details concerning sampling for age distributions in pedigree Ayrshire and Jersey cattle.

Breed.	Herdbook.		Total registered.	No. in sample.	Period during which ♀♀ born.	Herds making ♀ registrations.	
	Vol.	Year				Total	Sample
Ayrshire	63	1940	11,390	662	July '38-June '39	758	477
Jersey	52	1940	3,258	568	1940	-	334

The samples represented 5.8% of the females registered and 62.9% of the herds making entries in the Ayrshire herdbook; and 17.4% of the Jersey entries. The percentage of Jersey herds could not be calculated owing to the use of both prefixes and suffixes which leads to the scattering of entries from individual herds. Herd lists are given but these were found to be lacking for many herds. The samples are not quite random because entries in which the mating and calving breeders were different were excluded, the next suitable entry in these cases being selected.

In the process of collecting the data notes were made on a number of management and geographical variables which might have affected the age distributions. Each herd was classified according to locality, and according to whether or not milk recording and tuberculin testing were practised. In addition, each parent of the sample heifers were classified as being homebred or not homebred.

The data necessary for the estimation of the age distribution of the parents of registered bulls have not yet been collected. These distributions may well be different from those for heifers. It has been assumed, for reasons given by Donald and Itriby (1945) that practically all available pedigree Ayrshire and Jersey heifers will be registered in the herdbooks. Their parents should therefore be drawn proportionately from all age classes in the breeding stock.

SECTION II.

3. The Age Distribution of Pedigree Ayrshire and Jersey Cows.

The ages of cows at the time of birth of their daughters (calculated to the nearest month, but condensed into 6-month groups) are given in Table 3, and graphically in Fig. 1. The average Jersey dam was 53.76 months old at calving, which was just four months younger than the average Ayrshire dam in the samples taken. This difference appears to arise mainly at the time of first calving. Whereas the modal calving age for Jersey dams was 25-27 months, that for Ayrshires was 31-33 months. Thereafter the rates of decline in numbers with age seem to have been roughly parallel. The oldest cow found was a Jersey calving at 17 years 2 months of age, and the oldest Ayrshire was 14 years 11 months. As can be seen from the column giving the cumulative percentages, only about 10% of the dams lived to calve at more than 8 years of age. Not many of these would have had more than 5 lactations by this time. In Figures Ia and Ib, which are based on the same data as Table 3, but with 3-month intervals, it may be seen how the irregularity of calving interval has affected the position of the peak calving ages.

TABLE 3./

TABLE 3.

Age distribution of dams at birth of their daughters.

Age Group Mths.	AYRSHIRE No.	AYRSHIRE %	AYRSHIRE Cumulative %	JERSEY No.	JERSEY %	JERSEY Cumulative %
21-24	4	.60	.60	21	3.70	3.70
25-30	61	9.22	9.82	108	19.01	22.71
31-36	114	17.22	27.04	35	6.16	28.87
37-42	59	8.91	35.95	82	14.46	43.33
43-48	89	13.45	49.40	50	8.78	52.11
49-54	48	7.25	56.65	54	9.51	61.62
55-60	56	8.46	65.11	40	7.04	68.66
61-66	39	5.89	71.00	36	6.34	75.00
67-72	36	5.43	76.43	21	3.70	78.70
73-78	24	3.63	80.06	24	4.22	82.92
79-84	16	2.42	82.48	18	3.17	86.09
85-90	27	4.08	86.56	18	3.17	89.26
91-96	16	2.41	88.97	14	2.47	91.73
97-102	11	1.66	90.63	13	2.28	94.01
103-108	17	2.57	93.20	4	.70	94.72
109-114	11	1.66	94.86	10	1.76	96.48
115-120	11	1.66	96.53	6	1.06	97.54
121-126	5	.75	97.28	5	.88	98.42
127-132	5	.75	98.04	4	.70	99.12
133-138	4	.60	98.64	-	-	-
139-144	2	.30	98.94	1	.18	99.30
145-150	1	.15	99.09	2	.35	99.65
151-156	2	.30	99.39	1	.18	99.82
157-162	3	.46	99.85	-	-	-
163-168	-	-	-	-	-	-
169-174	-	-	-	-	-	-
175-180	1	.15	100.00	-	-	-
181-186	-	-	-	-	-	-
187-192	-	-	-	-	-	-
193-198	-	-	-	1	.18	100.00
Total ..	662			568		
Actual No.	661			568		
Average	57.76			53.76		

Average of both breeds .. 55.90 months.

FIGURE Ia.

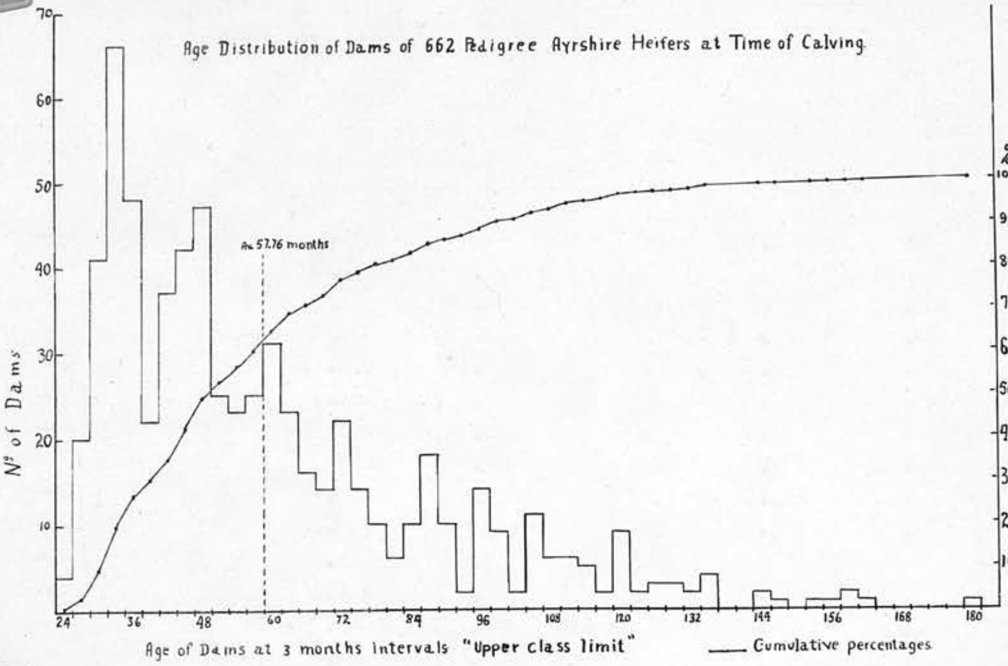
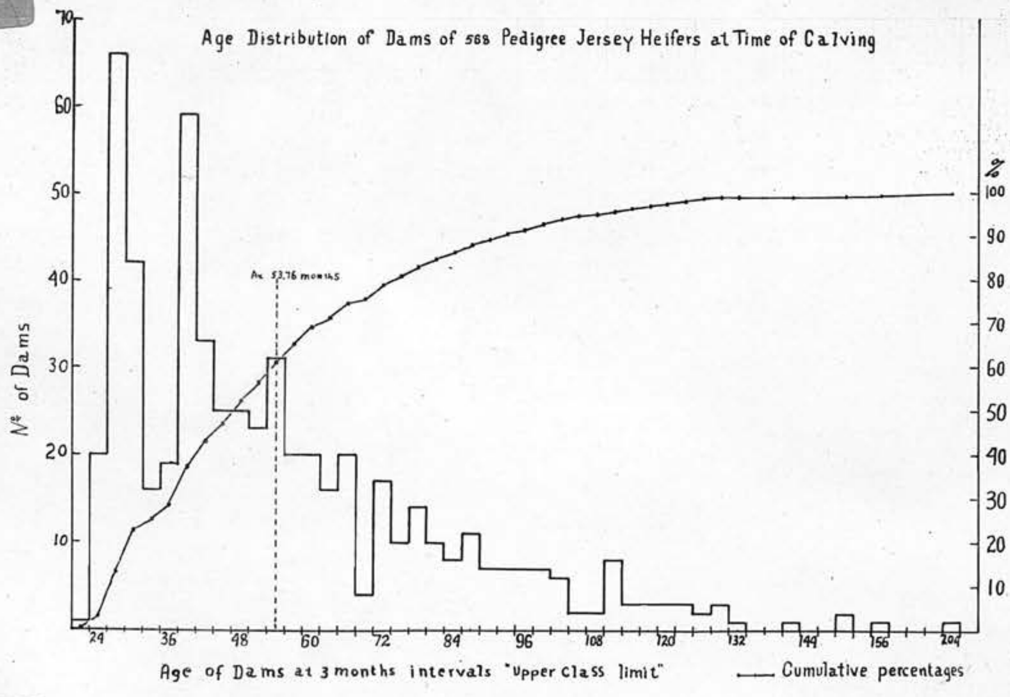


FIGURE Ib.



In the Ayrshires, the commonest age for first calving was around 32 months. The next peak was less pronounced and occurred 15 months later. During the next 15 months calvings were well spread out with only a slight peak 12 months after the previous one. Subsequent peaks are evident, but little significance can be attached to them since the intervals between them vary from 9 to 15 months, and the numbers on which they are based become small. Practically the same may be said of the Jersey data shown in Fig. Ib. In pedigree breeding herds such a result is not surprising. Regularity of breeding, while desirable, is not such a strong cause for culling as it would be in commercial herds, especially those in seasonal producing areas. Increased or decreased emphasis on winter milk would also tend to destroy the later peaks.

Figs. Ia and Ib also show the curves of cumulative percentages from which the percentage of animals less than any given age can be read off. Thus about 62% of both Jersey and Ayrshire dams are less than the average age for their breed. These curves will be referred to later regarding the supply of tested dams and proven sires.

4. Average Age, Average Length of Life and Expectation of Life.

The question whether it is allowable to regard the average age as being the same as the average length of life depends on the nature of the age distribution./

distribution. They are obviously not the same in human populations nor in sheep populations in which crossbred generations are regularly sold as a whole at a given age. Further, they would not be expected to be the same in horse populations in which animals may be kept even if they fail to breed. It has been shown (Donald, 1941) in a population of breeding sows, however, that when the rate of decline in numbers with age is at a constant rate, the average age is closely similar to the average length of life. It is necessary to know, therefore, whether the rate of decline with age is constant before this assumption can properly be made in this material.

For this purpose the data in Table 1 have been condensed into classes at yearly intervals to reduce the short-term variations. In this form the age distribution has been examined for the rate of decline in numbers by calculating the probability q_x that members of a given age class will not survive until the next age class. Also, the expectation of life has been calculated by the method adopted for insurance purposes (Spurgeon, 1938). The results for Ayrshire dams are given in Table 4.

TABLE 4./

TABLE 4.

Life table for pedigree Ayrshire cows based on distribution of ages at time of calving registered heifers.

Age	l_x (No.)	$L_x = \frac{1}{2}(l_x - l_{x-1})$	$T_x = \sum L_x$	$d_x = l_x - l_{x-1}$	$q_x = d_x/l_x$
0	179	163.5	572.5	31	.17
1	148	126.0	409.0	44	.30
2	104	89.5	283.0	29	.28
3	75	57.5	193.5	35	.47
4	40	41.5	136.0	3	-
5	43	35.5	94.5	15	.35
6	28	25.0	59.0	6	.21
7	22	16.0	34.0	12	.55
8	10	8.0	18.0	4	.40
9	6	4.5	10.0	3	
10	3	3.0	5.5	0	
11	3	22.0	2.5	2	
12	1	.5	.5	1	

Complete expectation of life, T_x/l_x = 572.5/179 = 3.2 years

Complete expectation of life at age 3 = 193.5/75 = 2.6 years

Average age at death or disposal .. .. = 3.2 years

Average age at calving $\sum(l_x \times \text{age})$ = 1487/662 = 2.25 years

The first age group ($l_x = l_0$) consists of cows entering herds as first calvers at 2-3 years of age, except that the few cows calving before 2 years of age have also been added. The next group of cows, designated age $l_x = 1$, were those calving at 3-4 years of age and so on. The columns headed L_x and T_x are necessary for the calculation of expectation of life. The number of cows not surviving from one age to the next are shown under d_x, and the probability of not surviving calculated from this is shown under q_x.

The values of q_x show a lack of uniformity which in the higher age classes is no doubt due to the lack of sufficient numbers. It seems reasonable to deduce nevertheless that there has been less culling during the first year of herd life than later. Pettit (1940) found a distinct increase in the rate of culling a year later in commercial herds. In Iowa and Kansas culling was intense for 2-3 year old cows and for cows 8 years old or more (Seath, 1940).

The complete expectation of life based on the present data is 3.2 years, that is 3.2 years after first calving, but to this must be added some portion of the lactation succeeding the last calf. This portion will depend on the proportions of cows sold just after calving, or sold at the end of their lactation, or sold during it on account of disease or accidents. Seath (1940) estimated the average time from last freshening to culling at 5.3 months. In terms/

terms of calves, those animals which reach the stage of calving the first time will, on the average, live to produce altogether four or nearly four calves. If the average interval between calvings is 1.1 years, the average number of calvings per cow will be just under four.

For cows which reached age group 3 (that is cows which were three years older than the first age group) the expectation of life was 2.6 years. Assuming a calf per year, this means that a cow which has had four calves will, on the average, continue her breeding life until she has had 2-3 more calves.

The average age at calving derived from Table 4 is 2.25 years. The actual age of the cows can be obtained by adding the average age at first calving, which is approximately 2.5 years, to the calculated age at calving, which is 2.25 years, giving a total of 4.75 years. This is very close to the actual value of 57.76 months given in Table 3, considering the approximations involved in condensing the data.

The average age of calved cows at the time of calving was not the same as the estimated complete expectation of life or length of productive life up to the time of the last calving. The expectation of life was about one year more than the average age. To conclude from the observed average age of 57.76 months that total herd life would be the same would lead to the considerable underestimate of about 12 months/

months if age at first calving is 30 months. The discrepancy is due to the fact that the rate of decline in class frequency with age is lower for the youngest cows than it is for the others.

These estimates apply only to those females which reach their first calving. They are possibly too low because a small proportion of all except first calvers are missed on account of not calving within the period of one year. They are not open to the objection that cows, although disposed of, may continue their productive life except insofar as they are sold to non-pedigree herds. The data on which they are based are unaffected by the number of owners a cow has had, and for present purposes it is immaterial if she eventually becomes part of a non-pedigree herd. It should, however, be pointed out that the Ayrshire population in 1939 was not stationary but increasing at the rate of about 8%, while the Jerseys were decreasing at this time even faster (Donald, 1944). What effect these changes would have on the estimated breeding life depends on the ways in which the increased or decreased populations are produced and this information is not yet available for these two breeds.

The corresponding calculations for the pedigree Jersey sample of dams is given in Table 5.

TABLE 5./

TABLE 5.

Life table for pedigree Jersey cows based on distribution of ages at time of calving of registered heifers.

Age	l_x	L_x	T_x	d_x	q_x
0	164	148	486	32	.20
1	132	113	338	38	.29
2	94	75.5	225	37	.39
3	57	49.5	149.5	15	.26
4	42	37	100.0	10	.24
5	32	24.5	63.0	15	.47
6	17	16.5	38.5	1	
7	16	12.5	22.0	7	
8	9	5.0	9.5	8	
9	1	2.0	4.5	- 2	
10	3	1.5	2.5	3	
11	-	-			
12	-	-			
13	-	.5	1.0	- 1	
14	1	.5	.5	1	

Complete expectation of life from date of first calving = 486/164 .. = 2.96 years

Complete expectation of life at age 3 .. = 2.62 years

Average age at calving, 1158/568 .. = 2.04 years

It appears here also that the rate of decline in age group frequency is not uniform. It changes enough with age to affect appreciably the assumption that the average age at calving is the same as the average length of life. As noted before, if the total productive life is required, there must be added to both these values some portion of the lactation succeeding the birth of the last calf. Owing to the limited numbers of animals in the samples, the differences between the Ayrshire and Jersey values cannot be given much weight.

It is of interest to compare these results with those of Lush and Lacy (1932). They estimated the curtate expectation of life for dairy cows of various breeds at 5.5 years at age 2-3 years. Since the curtate expectation is 0.5 year less than the complete expectation, the value for the latter should be 6 years. This is much higher than the 3.2 years found in the present Ayrshire data, higher than the 4.1 years found by Cannon and Hansen (1939) in American cow testing association data, and higher than the 4.1 years found by Pettit (1940) in Eastern Counties dairy herds. Lush and Lacy's data also give an average age for pedigree Ayrshire cows (obtained from herdbook registrations in the same way as the present data) of 4.95 years at time of service or 5.7 years at calving. This is much higher than the estimate of 4.75 years found here. It will be noted that Lush/

Lush and Lacy's data also show that expectation of life is greater than average age; the difference (6 - 5.7) would be greater if an average age for all breeds had been given to compare with the overall figure for expectation since the Ayrshire group of cows was about 0.5 year higher in average age than the Jersey, Guernsey and Holstein groups. Cannon and Hansen (1939) give the average age of cows in tested herds (20-34% pedigree) as 4.7 years.

5. Age of Cows in Relation to Milk Recording, Tuberculin Testing, Homebreeding, and Country.

For the purposes of this investigation, milk recorded means that the herds from which the sample heifers were registered were members of milk recording societies as noted in the herdbook (this information was not given in the Ayrshire herdbook); tuberculin tested means that the herds were described in the herdbooks as being attested or tuberculin tested, or as producing certified milk; homebred means that the sires and dams concerned were registered by the breeders who registered their daughters. To avoid the inclusion among homebred animals of bulls and cows which were purchased in their dams, no heifers have been included in the sample which had different mating and calving breeders.

The age distributions of the sample cows classified according to the above distinctions are given/

given in detail in Tables 13 and 14 in the Appendix. The necessary comparisons can be made more easily with the aid of Table 6 in which the average ages for each group are given, and also the numbers and percentage of cows falling into each of three large subdivisions covering the whole age range.

TABLE 6./

TABLE 6.

Average ages at calving of pedigree Jersey and Ayrshire cows in relation to milk recording, tuberculin testing, homebreeding and country.

(The columns headed '% distribution' give the percentages of animals in the age groups up to 3 yrs., 3-6 yrs., and 6 yrs. and over.)

	JERSEY			AYRSHIRE		
	Average Age (mths.)	No.	% distribution	Average Age (mths.)	No.	% distribution
M.R.	53.3	450	30 - 50 - 20			
Non-M.R.	55.7	118	25 - 50 - 25			
T.T.	52.9	376	31 - 50 - 19	56.7	515	27 - 51 - 22
Non-T.T.	55.5	192	26 - 49 - 25	61.4	147	26 - 45 - 29
H.B.	50.2	336	35 - 48 - 17	55.1	473	32 - 47 - 21
Non-H.B.	58.9	232	21 - 51 - 28	64.4	189	16 - 53 - 31
England	53.8	568	29 - 50 - 21	52.7	137	28 - 53 - 19
Scotland	-	-	-	59.1	525	27 - 48 - 25

M.R. = Milk Recorded.
T.T. = Tuberculin Tested.
H.B. = Homebred.

With respect to Milk Recording, there was a slightly higher average age for non-recorded than for recorded cows, but the difference is too small to rely on. The corresponding data for Ayrshires is lacking since there is no information in the herdbook on the subject.

Non-tuberculin tested cows of both breeds showed a higher average age than tested cows owing to the excess of older cows. Whether this difference is due to culling on account of tuberculosis, or whether it is due to other factors such as milk recording which may be more general in T.T. than non-T.T. herds is not clear. The degree of association between milk recording and tuberculin testing cannot be adequately tested with the present data since it needs to be considered on a herd basis as well as on a cow basis. As far as the latter is concerned the Jersey data offer some help. As shown in Table 6, 450 out of 568 Jersey cows were in milk recorded herds, and 376 were in tuberculin tested herds. If there were no correlation between milk recording and tuberculin testing, the number of cows which were both milk recorded and tuberculin tested should have been approximately 450 x $376/568^2$, or 52%. In the same way, the other combinations can be calculated, giving the following results:

	Expected		Observed	
	No.	%	No.	%
M.R. and T.T.	298	52	330	58
M.R. only	152	27	120	21
T.T. only	78	14	46	8
Neither	40	7	72	13

In/

In the present sample, there is an excess of animals which are both M.R. and T.T., and also more than the expected number which is neither M.R. or T.T. Animals which are only M.R. or only T.T. are less numerous than expected. This suggests that there is a tendency for milk recording and tuberculin testing to be associated. If the sampling process were such as to give small herds the same weight as large herds the result might be different. It is possible, however, that the lower average age of tuberculin tested dams is not due only to the culling of reactors, but also in part at least to the culling of low yielders.

In both breeds, non-homebred cows were of distinctly greater average age than homebred cows. Although it is possible that cows last longer if they change owners and environment, a more important reason for the difference may be that all recently established herds must be composed, for a considerable time, of mature purchased stock and a high proportion of immature homebred stock. As will be shown elsewhere, there is always a considerable number of newly established herds. Not all purchased animals are for newly established herds, so that the proportions of non-homebred animals shown in Table 6 do not show the frequency of exchanges due to original purchases. The number of animals which changed owners appears to be rather high, especially among Jerseys, of which 41% in/

in the sample were not bred in the herd from which their daughters were registered. As may be seen from Table 14 (Appendix) a considerable number of these were obtained from the Island. Even among the Ayrshires, 28.5% of the dams were not homebred.

Since only a small number of Jerseys were kept in Scotland in 1940, the comparison of ages in Scotland and England is confined to Ayrshires. In the sample, 21% of the daughters were registered by English herds. This is higher than the 17% reported by Donald (1944), but is based on a much smaller sample. The average age of the dams in Scottish herds is considerably higher than that of the English dams, and the difference arises from the greater number of cows over 6 years of age in Scotland. Whether this is due to a higher proportion of comparatively young herds in England or due to some other cause such as a relatively low wastage rate in Scotland, cannot as yet be determined.

SECTION III.

6. Age Distribution of Ayrshire and Jersey Bulls.

Although it is generally admitted that most bulls are discarded before their breeding value is known, details concerning the age distributions of herd sires are scarce. Recent developments in artificial insemination and breeding for higher milk production have emphasized the difficulty of securing proven sires. But it is not new for Arthur Young (quoted by Euren, 1882) noted in 1794 that in Suffolk there was no such thing as a bull more than 3 years old. This was probably an exaggeration, but there was no doubt much truth in it. Even now when the value of progeny testing is much more clearly realised, the number of bulls in use which can have been progeny tested must be small. Buchanan Smith and Robison (1931) found an average age for pedigree bulls of four dairy breeds at the time of birth of their progeny of 3.687 years. Since many of these bulls will not have survived until their progeny were born, this value may be too high. Lush and Lacy (1932) found that 85% of the bulls in Iowa Cow Testing Association herds were less than 5 years of age, and 91% were less than 6 years old. Scorgie (1942) found in the Jersey breed that only 46 out of 632 bulls were over 5 years of age. Donald (1944) estimated the average service life of bulls at 2-2.5 years, but this included bulls used in non-pedigree herds.

It/

It has been thought useful to examine the ages of bulls in pedigree herds of Ayrshires and Jerseys from the same point of view as those of cows. The samples were obtained at the same time and in the same way as those of the dams of registered heifers.

Table 7 shows the distribution of bulls in 6-month age classes, and Figs. 2a and 2b present the same data graphically along with the cumulative percentage curve from which may be read off the percentage of animals falling above and below any given age. It will be seen that the average ages of Jersey and Ayrshire bulls differ only by about $1\frac{1}{2}$ months, the youngest animals (not shown separately) being Jerseys, and the oldest being Ayrshires. At the time of conception of his daughter, the average Jersey bull was about 35 months, and the average Ayrshire about $36\frac{1}{2}$ months old. If it is assumed, ignoring the breed difference, that the age at first service is 12 months, the average time in service of a bull when one of his daughters is conceived becomes 2 years. On the same assumption, Buchanan Smith and Robison's data for four dairy breeds together also lead to an estimate of almost 2 years.

The oldest Jersey bull in the sample was 11 years, and the oldest Ayrshire 14 years, but the chances of a young bull reaching these ages were very slight for, as Figs. 2a and 2b show, the numbers of bulls in the various age classes decline very rapidly after the peak at 2.5-3 years.

TABLE 7.

Age distribution of sires at time of conception of their daughters.

Age in months.	AYRSHIRE No.	AYRSHIRE %	AYRSHIRE Cumulative %	JERSEY No.	JERSEY %	JERSEY Cumulative %
10-15	64	9.67	9.67	53	9.33	9.33
16-21	114	17.22	26.89	91	16.02	25.35
22-27	110	16.61	43.50	100	17.61	42.96
28-33	73	11.03	54.53	85	14.96	57.92
34-39	78	11.78	66.31	72	12.68	70.60
40-45	55	8.31	74.62	44	7.74	78.34
46-51	45	6.80	81.42	30	5.59	83.63
52-57	40	6.04	87.46	22	3.87	87.50
58-63	22	3.33	90.79	20	3.52	91.02
64-69	14	2.11	92.90	16	2.82	93.84
70-75	11	1.66	94.56	6	1.05	94.89
76-81	6	.91	95.47	7	1.24	96.13
82-87	8	1.21	96.68	9	1.58	97.71
88-93	4	.60	97.28	5	.88	98.59
94-99	4	.60	97.88	3	.53	99.12
100-105	1	.15	98.04	1	.18	99.30
106-111	3	.45	98.49	1	.18	99.47
112-117	5	.75	99.24	1	.18	99.65
118-123	-	-	-	1	.18	99.82
124-129	1	.15	99.40	1	.18	100.00
130-135	1	.15	99.55	-	-	-
136-141	1	.15	99.70	-	-	-
142-147	1	.15	99.85	-	-	-
148-153	-	-	-	-	-	-
154-159	-	-	-	-	-	-
160-165	1	.15	100.00	-	-	-
Total ..	662			568		
Actual No.	565			462		
Average	45.54			43.95		

FIGURE 2a.

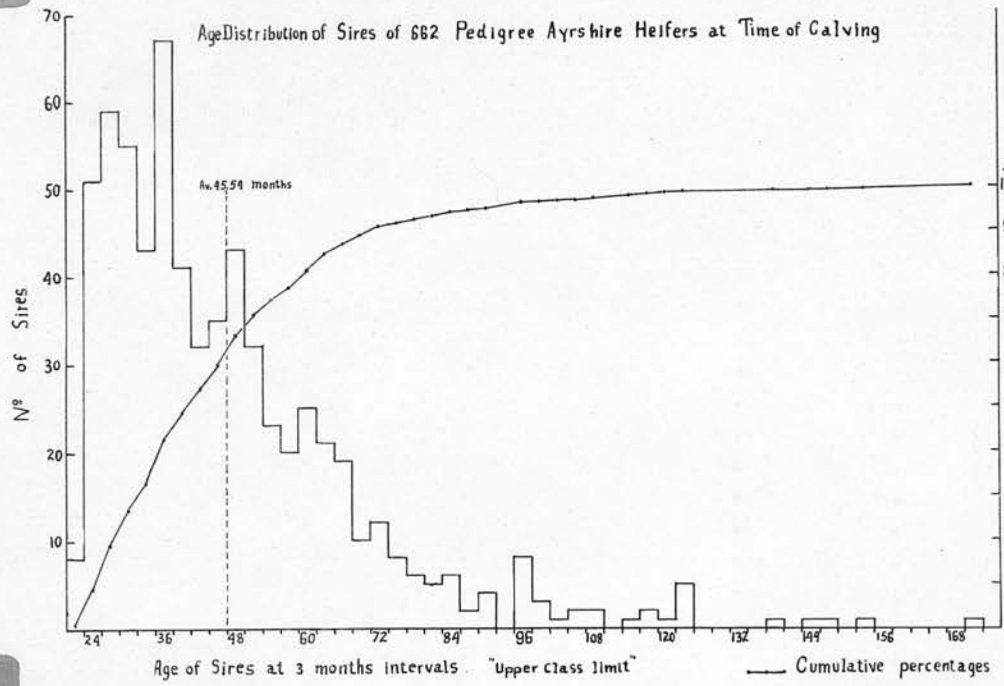
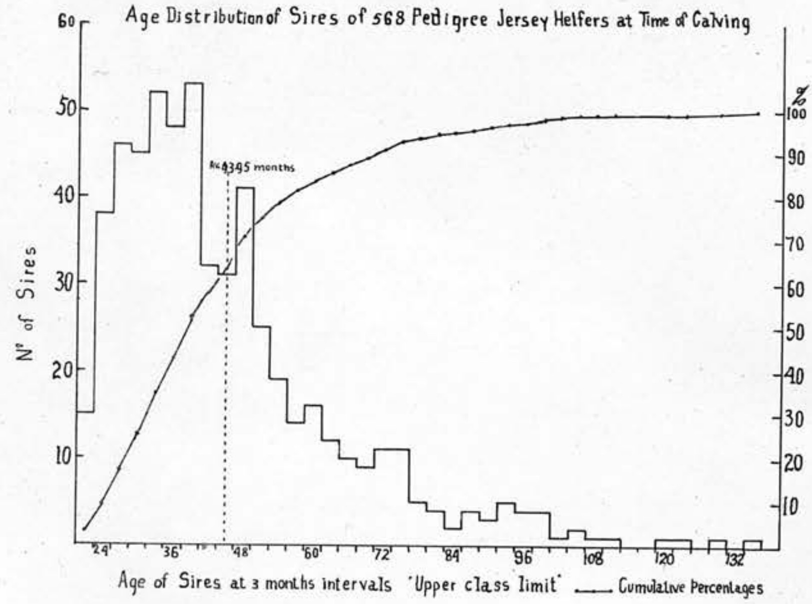


FIGURE 2b.



The fact that the youngest age class does not appear to be the most frequent (although clearly there must be more animals in the youngest age group than in any other provided the population is not declining in numbers) shows that the age distribution of sires is subject to difficulties not affecting dams to the same extent. Firstly, it cannot be assumed that bulls of each age group are used with a frequency which depends only on their numbers and not their age. Figs. 2a and 2b show that in both breeds sampled the youngest groups of bulls at least, and possibly the next youngest also, are not used in proportion to the numbers of them which must have existed. In those herds which had more than one bull in service, the oldest bulls must have been used more freely than the younger, although this is a generalization which does not necessarily apply for instance to the oldest age groups. The possibility of using some animals more frequently than others cannot apply to females except to the extent that a breeder who values high yields more than regularity of breeding may actually breed more often in a given time from the moderate yielding cows than from the highest yielders which may be allowed to calve at longer intervals to encourage higher yields.

Secondly, a distinction must be made between the average age of the sires of the daughters taken in the samples and the average age of the actual sire population. Table 7 gives the former but it will be noted/

noted that the actual number of sires used is much less than the number of daughters in the samples owing to the fact that some sires, especially those in the larger herds, are represented by more than one daughter. For some purposes, it is important to know what proportions of cows are sired by bulls of the various ages, in which case the former calculation is of value. For other purposes, the age distribution and average age of the sire population itself is wanted. This cannot be obtained from the data at present available partly because some sires will not have any registered daughters, and partly because of the effect of sires' ages on the amount of use made of them. However, it might be expected that the average age of the actual sire population would be less than that shown by the sires of registered daughters and given in Table 7. The average age of sires has been calculated after excluding records of all but the first daughters in the samples. The average age of the 565 Ayrshire sires at the time of birth of their daughters was thus reduced from 45.54 to 44.69 months, and of the 462 Jersey sires from 43.95 to 43.23 months. As pointed out above, this does not give the average age of all bulls actually in use, but apart from sampling errors, indicates that this age will probably be less than that obtained by the method of Table 7 since it is based on relatively more of the youngest sires.

Owing/

Owing to the nature of the data, they are unsuitable for the comparison of average age with expectation of life.

7. Age of Bulls in Relation to Milk Recording, Tuberculin Testing, Homebreeding and Country.

The effects of these four factors have been studied in the same way as that used for dams. Any effects observed are to be interpreted as applying to the average ages of the sires of all females in the samples regardless of whether some sires appear more than once in the data. As before, the condensed data are presented in Table 8, while the detailed data are recorded in the Appendix, Tables 15 and 16. The latter include details of the number and percentages of herds represented in the samples which fall into the various categories, as well as the number and age distribution of Island-bred Jerseys here classed as non-homebred.

TABLE 8./

TABLE 8.

Average ages, at time of service, of pedigree Jersey and Ayrshire bulls in relation to milk recording, tuberculin testing, homebreeding and country.

(The columns headed '% distribution' give the percentages of bulls in the age groups: up to 21 months, 22-45 months, and 46 months and over.)

	JERSEY			AYRSHIRE		
	Average Age (mths.)	No.	% distribution	Average Age (mths.)	No.	% distribution
M.R.	35.4	450	26 - 51 - 23	-	-	-
Non-M.R.	33.2	118	23 - 61 - 16	-	-	-
T.T.	35.5	376	26 - 51 - 23	36.6	515	26 - 48 - 26
Non-T.T.	34.0	192	23 - 57 - 20	36.4	147	29 - 46 - 25
H.B.	32.4	131	33 - 48 - 19	31.6	88	40 - 47 - 13
Non H.B.	35.7	437	23 - 55 - 22	37.3	574	25 - 48 - 27
England	35.0	568	25 - 53 - 22	35.3	137	26 - 52 - 22
Scotland	-	-	-	36.9	525	27 - 47 - 26

M.R. = Milk Recorded.
T.T. = Tuberculin Tested.
H.B. = Homebred.

Jersey sires in milk recorded herds appear to include rather more old bulls than those in non-recorded herds, but apart from the rather small numbers in the non-recorded group, it seems likely that the observed difference in average age is connected with the size of non-recorded herds and the possibility of keeping old bulls in them. The same considerations apply also to the comparison of tuberculin tested with non-tuberculin tested herds which shows in both breeds a slightly greater average age of sires in the former.

More striking differences are to be found between the homebred and non-homebred sires. Homebred sires are more numerous in the youngest age group and less numerous in the oldest age group than the non-homebred sires, and the result is that the homebred sires are 3.3 and 5.7 months younger on the average than the non-homebred sires in the Jersey and Ayrshire samples respectively. This may be due to a practice of using young sires occasionally before sale as a check on their vigour and fertility. The use of homebred sires appears to have been rather more common among Jersey breeders than among Ayrshire breeders. Reference to Table 6 (p.22) shows that non-homebred Jersey dams were relatively more common than non-homebred Ayrshire dams so that the breed difference in respect of bulls may be due to a different frequency of purchase of bulls <u>in utero</u>, especially in Island-bred/

bred dams.

The Ayrshire sires in English herds averaged 1.6 months less in age than those in Scottish herds, largely owing to the smaller proportion of old animals. This difference, if supported by larger numbers, might be a consequence of smaller herd size, or of a greater proportion of recently established herds.

SECTION IV.

8. Replacement Rates of Pedigree Jersey and Ayrshire Dams.

Apart from their economic aspects, replacement rates in herds of cattle are of importance as a measure of the amount of selection practised among the available heifers. If the expectations of life, as calculated in Tables 4 and 5, are used as a basis, the replacement rates of the Jersey and Ayrshire dams in the samples are 100/3.0 and 100/3.2% respectively. The crude values of 33% and 30% ought to be modified to account for changes in population size, but this cannot be readily done with the information available. Owing to the rapid growth of the Ayrshire breed about 1939, the rate given for it is almost certainly too high. The actual correction to be applied will depend on the nature of the population change, that is to say, on whether it is achieved by taking in more young stock, or by keeping the existing breeding animals for longer.

If allowance is made for the fact that the estimates of productive life given in Table 1 (p.3) include portions of the last lactation, the present estimate of breeding life agrees well with published data on productive life, in spite of the fact that it is based on pedigree herds only. Thus the estimate that a pedigree Jersey cow has an expectation of herd life of 3 years, and an Ayrshire cow 3.2 years plus a portion of the last lactation, agrees with previous experience/

experience that productive life is about 3.2-3.6 years.

In a herd of 100 calved cows kept at this size, 30 heifers would have to be drafted in each year to replace 30 cows drafted out, assuming a replacement rate of 30%. If each cow calved at the same time each year, and the sex ratio was 1.0, there would be 50 heifer calves for replacement purposes. With a calving interval of 13 months, there would be 12/13 of 50, or 46 heifer calves. From this number must be deducted deaths from before birth until first calving. Losses of this kind vary, but allowing 5% stillborn and 10% dead or diseased before calving, a breeder who intended to keep all 46 heifer calves would have about 39 at calving time if all were fertile. This would be 9 more than required for replacement purposes. A surplus of 9 does not provide a very large reserve against temporary or complete sterility nor does it allow a very large margin for selection at any age against unthrifty or undesirable animals. This may well be an overestimate as Lovell and Hill (1940) report that, in addition to 4.4% stillbirths, there were 5.5% abortions in milk recorded herds in England and Wales. Selection on dams' milk records must be at a very low level among heifer calves.

9. <u>Amount of Information about Heifer Replacements.</u>/

9. <u>Amount of Information about Heifer Replacements.</u>

Lush (1943) has shown that the evaluation of a cow's milking capacity increases with the number of lactations. Up to four lactation records improve the estimate of her ability, but subsequent lactations do not add much further accuracy. It thus becomes of interest to know (a) how many heifer calves may be available for replacements from cows of various ages and therefore of various degrees of tested milking capacity; and (b) to what extent fully and partly tested cows are replaced by untried heifers from fully or partly tested cows. For this purpose the data in Figs. 1a and 1b (p.11) may be used. These have been modified slightly to smooth the decline since in a very large sample it would not be possible for an older age group to have more animals in it than a younger group except in a declining population, or when the intake of heifers is very irregular from year to year.

Assuming that cows of all ages are equally likely to produce heifer calves and that these calves have equal chances of surviving the risks of death and disease up to the time of first calving, it may be inferred that the various age groups are all capable of providing their own replacements (except perhaps the oldest which may have a very high replacement rate, and which, on account of small numbers, may be affected by fluctuations of the sex ratio). This inference implies that the values of d_x/

d_x are fairly constant from one age group to the next.

The 179 Ayrshire and 164 Jersey cows appearing as replacements in the two populations of cows shown in Tables 4 and 5 can now be classified according to the amount of information about their dams with the aid of the cumulative percentage data in Table 3 and Figs. 1a and 1b.

TABLE 9./

TABLE 9.

Percentage distribution of replacement heifers in relation to the time which their dams have spent in the milking herd.

Dams' time in herd (years)	At Birth. Ayrshire	Jersey	Smoothed Average.	At 1 year old.	At 2 years old.
0-1	27.0	28.9	28	5	5
1-2	22.4	23.2	23	30	14
2-3	15.7	16.5	16	22	28
3-4	11.0	10.1	10	13	16
4-5	6.0	7.4	7	8	9
5-6	6.0	5.6	6	7	8
6 and over	12.0	8.3	10	15	20
Totals ...	100.1	100.0	100	100	100

This table shows that at the time of birth, 28% of heifer calves are out of first calf cows, which are just beginning their life in the milking herd. Another 23% are out of cows which have spent a year in the herd and have usually completed one lactation and are beginning the next; and so on. When these calves are one year old, 5% will be out of dams which do not have more than one or part of one lactation. Another 30% will be out of dams which have completed one lactation and have started or completed a second, and include 23% (out of the original 28%) from first calf cows which went on to a second calving, and 7% from second calf cows which failed to go on to a third calving. The same process can be continued for another year giving the percentages in the last column, which shows the amount of information about their dams which may be expected at the moment of entering the year in which they will normally be added to the milking herd. Thus 5% of heifer calves may be expected to have dams with no more than one lactation, and another 14% with dams having only two lactations. Under present replacement rates it should not be very difficult to avoid the use of heifers from single lactation cows. In small herds, of course, there may well be years in which the sex ratio makes this impossible. In this discussion it has been assumed that years, calvings and lactations increase at the same rate, whereas in practice it is likely that the average/

average calving interval will be more than one year. A proportion of the heifers will therefore at two years of age have somewhat less than the specified amount of information about their dams.

In some herds, long calving intervals, abortion, and disease may leave no room for selection at all. As to whether it is better to keep a heifer from a cow with only one lactation rather than from another cow with two or more lactations will have to depend on circumstances. Cows discarded after one lactation for poor yield will have daughters that are better than their dams owing to regression. Insofar as one lactation is the least accurate amount of information about a cow, the offspring of first lactation cows which have low yields on account of accidents of environment may be expected to be average in merit, and perhaps even better than the progeny of cows which, over two lactations, have shown themselves to be repeatedly poor producers. In general, the best policy may be to keep calves from one lactation cows for which some good reason for low production exists in preference to cows with two or more lactations which have continued to be low yielders without reasonable excuse. Calves from the former should be of at least average performance, whereas calves from the latter more carefully tested dams should yield less than the herd average although better than their dams. If replacement rates permit, it is of course better/

better to retain neither kind. The replacements necessary owing to disease in some districts of Britain (Wright, 1933) appear to be greater than in New Zealand (Candy and others, 1943) where it is calculated that the improvement possible from selection of heifers according to dams' yields is very slight. Seath (1940) concluded that the culling of dairy cows in Iowa and Kansas had led to an hereditary increase in production of only 25-38 lb. of milk per year. There is the further difficulty that by no means all pedigree herds are milk recorded. As shown above, about one in every five Jersey cows in 1939 was not recorded.

10. Amount of Information about Sires.

If the estimate of 10% of bull calves retained for breeding in the Red Poll breed (Donald, in press) be taken as a guide for dairy breeds, Table 9 shows that theoretically all these could be obtained from cows with four or more lactations even if selection was made at birth, and even if 25% of the pedigree herds were not recorded and reared no bulls. This is far from being the case. At four of the principal Scottish pedigree Ayrshire bull sales in 1944-45, the bulls offered were accompanied by dams' records as follows:

TABLE 10./

TABLE 10.

Distribution of 296 Attested pedigree Ayrshire bulls according to number of lactations shown for their dams.

Dams No. of lactation records	No.	Bulls %
0	7	2.4
1	58	19.6
2	79	26.7
3	66	22.3
4	48	16.2
5	14	4.7
6	13	4.4
7 and more	11	3.7

About half of this highly selected sample of bulls was sold with two or fewer lactation records of their dams, in spite of the fact that bulls from first calf cows are reared less often than bulls from older cows. The/

The reasons for this are probably connected with (a) the fact that bull breeding is limited to a proportion of all herds and thus all the necessary old cows are not available; (b) it may be found easier to sell bulls from heifers with a good record than from older cows with poorer records; (c) a higher saleability of moderate yields and high butterfat % from young cows than of higher yields and lower butterfat % from older cows; and (d) the presence of high performance ancestors in the pedigree.

Apart from the amount of information about the dams of bull calves which may be used in selection, some idea of the extent to which the sires of bull or heifer calves have been proved by progeny tests may be obtained from the age distribution of the sires of daughters. If the age distribution of the sires of bulls is not the same as that of the sires of heifers, this method could not be used for young bulls with the information at present available. Using the data in Figs. 2a and 2b on the age distribution of sires at the time of conception, Table 11 may be constructed. It is based on the assumption that a sire's first year's crop of daughters will have completed their first lactations when the sire is 6 years old.

TABLE 11./

TABLE 11.

Percentage distribution of daughters according to age of sire.

Sire	Sire's age at service (years)	% of daughters		
		Ayrshire	Jersey	Average
Unproven	Up to 2	33	35	34
	2-3	27	28	27
	3-4	18	18	18
	4-5	11	8	10
	5-6	5	6	6
Proven	6 & over	6	5	5

Thus at the time of service about 5-6% of bulls may have been proven although not necessarily with an adequate number of daughters. By the time they are 2 years old, a year's crop of daughters will have accumulated information about their sires although more than half of their sires will no longer be alive. Only those daughters sired by bulls four years old and over, that is about 20% of all daughters, may have tested sires by the time they are two years old. Since selection of sires on the evidence of their daughters' milk yields can be applied only to those over 6 years of age, it is limited to 5-6% of sires actually in use for pedigree breeding, and even fewer from the whole pedigree bull population in pedigree herds. This suggests that selection on this basis is almost negligible in practice.

The chances that any mating will be between cows with four completed lactations and bulls of 6 years or more are apparently small. If no special effort is made to mate old cows with old bulls, the chances of such a mating taking place are about 1% since only 20-25% of cows have four or more lactations and 5% of bulls in use are over 6 years old.

11. <u>Relation between Ages of Sires and Dams.</u>/

11. <u>Relation between Ages of Sires and Dams.</u>

To test the assumption that matings take place independently of the age of the mates, the distribution of sires by age has been worked out for dams falling into three different age groups. The results are given in Table 12.

TABLE 12./

TABLE 12.

Distribution of daughters according to age of parents (in months) at mating.

AYRSHIRE			Sires.		JERSEY			Sires.	
Age of Dam	Age of Sire	No. of Daughters	% of total	% of group	Age of Dam	Age of Sire	No. of Daughters	% of total	% of group
13-48	10-39	292	44.10	71	10-45	10-36	246	43.30	70
	40-51	57	8.60	14		37-51	62	10.90	18
	52-75	48	7.20	12		52-75	33	5.80	9
	76 and over	16	2.40	4		76 and over	9	1.60	3
49-87	10-39	107	16.20	61	46-87	10-36	95	16.70	56
	40-51	33	5.00	19		37-51	39	6.90	23
	52-75	23	3.50	13		52-75	24	4.20	14
	76 and over	13	2.00	7		76 and over	13	2.30	8
88 and over	10-39	40	6.00	55	88 and over	10-36	19	3.3	40
	40-51	16	2.40	22		37-51	14	2.4	30
	52-75	10	1.50	14		52-75	7	1.3	15
	76 and over	7	1.10	9		76 and over	7	1.3	15

Ayrshire: Age distribution of all sires.			
10-39	40-51	52-75	76 and over
66	15	14	5

Jersey: Age distribution of all sires.			
10-36	37-51	52-75	76 and over
63	21	11	5

It will be seen that in both Jersey and Ayrshire breeds the proportion of young bulls used declined as the cows became older. The assumption that matings are independent of age is therefore not valid. The use of young bulls on young cows may be affected by the belief that young bulls can settle heifers more easily than old bulls, and by the inability of immature cows to bear the weight of mature bulls. In spite of the tendency to mate old bulls with old cows, the number of daughters produced by cows with more than four lactations by sires of more than 6 years of age is very small. Taking the two breeds together only 65 out of 1230 daughters were by bulls over 6 years, and of these only 14 were out of dams which were over 7 years of age. This result is only slightly in excess of the 1% estimated above, and shows that although there may be a tendency to use proven bulls on proven cows, there are so few animals of this kind that preferential matings among them do not increase the number of their progeny very much above that expected from purely random matings (in respect of age).

12. <u>Discussion</u>.

The estimates of productive life, however reached, cannot be applied confidently to individual herds nor to restricted areas (unless the data are confined to such areas), but they all agree that the reproductive lifetime of both cows and bulls is comparatively short compared with that of individual animals of both sexes which may reach an age of 16 years or more. The present investigation has been made from the point of view of the annual crop of calves rather than of the population of breeding animals from which they come. This would be a considerable objection if the main questions of interest were milk production or disease, but not if the performance of the parents of the new generation is wanted for genetical reasons.

The published studies of the causes of removal of cattle from herds (for example, Wright, 1933; Seath, 1940; N.Z. Dairy Board, 1941; Scott Watson, 1944) show that the incidence of the various diseases varies considerably as does the percentage of animals sold for low yield or for further use elsewhere. As the disease wastage declines it seems likely that disposals on account of low yield rise, the result being that although replacement rates vary, cows and bulls everywhere tend to be of a comparatively low age. Breeding herds which have low losses through disease take the opportunity of culling and keeping their stock young. This is understandable as a measure of securing/

securing the immediate advantages of higher average yield and low depreciation, but it means that the search for progeny of sufficiently tested parents is not made much easier by improved disease control in breeding herds.

As has been shown such progeny are very scarce. Since many pedigree herds are very small, it must happen that they contain many of the available old and tested cows but cannot have progeny tested bulls with which to mate them because in one-sire herds the bulls cannot be kept for long in use without entailing close inbreeding. Assuming that the large herds, not subject to this limitation, have the usual proportion of old cows, it is not easy to see how more than a few of the small herd owners can hope to obtain the sons of tested parents, even if they are not particular about the appearance of the sons. If 10% of the available bull calves are retained for breeding by 50% of breeders, each bull breeder will have to rear 20% of his bull calves, but only 1-2% of them are likely to be produced by tested parents. Sons of living tested bulls out of dams of all ages will be more numerous (5-6%) but still far too few even if all are retained.

Under the circumstances it would seem desirable to ensure that as many sires as possible are progeny tested, even if they are dead, and to follow this up by encouraging the retention and testing of their sons.

Factors/

Factors affecting the most desirable age composition of pig herds have been discussed by Olbrycht (1943) and Dickerson & Hazel (1944). It has been pointed out that the keeping of animals past the age at which their breeding value can be adequately assessed increases the interval between generations. What is gained by increased accuracy in estimating performance ability is more than lost by the delay in applying selection to improve the next generation. For characters like colour or horns where accurate judgments may be made very early in life, the fastest progress in selection can obviously be made if breeding animals are discarded as soon as there is sufficient progeny to replace them. Milk production is a character which usually needs to be judged over three or four lactations. As this is about the usual length of time in a herd, the requirements for selection on the dams' side correspond fairly well with practice. Selection for characters like constitution or longevity which at present need much longer for adequate testing would extend the interval between generations and slow up progress for simultaneous selection for milk. If the latter is the major objective, it would seem best for breeders to cull comparatively lightly up till the third or fourth lactation and then heavily. The gradual slope of the age distribution curve suggests that there is no heavy culling at this time. Cows which/

which have survived culling up to their fourth lactation will usually be the best producers and their retention is desirable for immediate economic reasons. Possibly also they are retained for longer on account of their supposed breeding value, or because suitable replacements are not available in sufficient numbers. Nevertheless, this increases the interval between generations and adds little to what is known about the breeding value of the cows concerned. Since selection on the basis of cows' records is subject to considerable regression, it would appear to be advantageous, from the genetical point of view, to limit the number of cows with more than four lactations to those which are good enough to be dams' of sires.

SUMMARY.

1. Detailed age distributions for pedigree cattle hitherto lacking have been obtained from herdbook data on 662 Ayrshire and 568 Jersey dams, and equal numbers of bulls classified according to the following criteria: tuberculin testing, milk recording, homebreeding, and country.

2. About 10% of dams lived to calve at more than 8 years of age, and about 62% of the dams of both breeds were of less than the average age.

3. The expectation of life was found to be 3.2 years after first calving for Ayrshires, and 3.0 years for Jerseys, i.e., four or nearly five calves, but only 3 lactations. The average age at calving was 4.75 years, which is about 1 year less than the expectation of life if it is assumed that a cow calves for the first time at 2.5 years of age.

4. Non-milk-recorded and non-tuberculin-tested cows showed a greater average age than milk recorded and tuberculin tested cows. In view of the tendency for breeders to adopt both milk recording and tuberculin testing, it is not clear which factor depressed the average age. Of 568 Jersey cows, 58% were both M.R. and T.T., 21% were M.R. only, 8% were T.T. only, and 13% neither M.R. nor T.T.

5./

5. Homebred cows were much younger on the average than non-homebred cows (4.4 years and 5.1 years respectively). This difference is attributed to the high frequency of recently established herds, the mature purchased stock of which is necessarily older than the homebred stock. Among Jerseys, 41% were found to be non-homebred, and among Ayrshires, 28%.

6. Cows in Scottish herds had a higher proportion of old cows than English herds.

7. The average ages of Jersey and Ayrshire bulls were 35 and 36.5 months at the time of conception of their daughters, indicating an average service life of 2 years. The real average age may be less than found since evidence is given showing that young bulls are less freely used than older bulls.

8. Age differences in the sires of pedigree heifers in consequence of milk recording or tuberculin testing are not appreciable, but homebred sires were 3.3 and 5.7 months younger on the average for Jerseys and Ayrshires, than non-homebred sires. It is suggested that this may be due partly to the practice of testing young bulls before sale. Homebred sires appeared to be more common in Jersey than in Ayrshire herds.

9./

9. Consideration of the age distributions shows that there can be very little selection among heifer replacements and that the chances of mating between a sire 6 years or more old and a dam with 4 completed lactations is about 1%. Even if all sires 6 years or more old were proven raisers of milk production, such matings would not supply nearly enough young bulls.

10. A tendency was found for the mates of young sires to be younger than the mates of old sires, but owing to the small numbers of aged bulls and cows this tendency did not increase the numbers of matings between the latter much above those expected on the basis of no correlation between the ages of mates.

11. The possibility of obtaining offspring from tested parents, and the most desirable age composition of herds, is discussed in the light of the observed age distributions.

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APPENDIX TABLES

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TABLE 13.

Ages of 662 pedigree Ayrshire cows in relation to tuberculin testing, homebreeding and country.

Age at calving. (months)	T.T. No.	T.T. %	Non-T.T. No.	Non-T.T. %	Homebred No.	Homebred %	Non-Homebred No.	Non-Homebred %	English No.	English %	Scottish No.	Scottish %
19-24	2	0.39	2	1.36	2	0.42	2	1.06	2	1.46	2	0.38
25-30	55	11.07	6	5.44	51	11.21	10	6.35	17	13.87	44	8.76
31-36	84	27.38	30	25.85	96	31.50	18	15.87	19	27.74	95	26.86
37-42	50	37.09	9	31.97	38	39.53	21	26.98	22	43.80	37	33.90
43-48	70	50.68	19	44.90	67	53.70	22	38.62	19	57.66	70	47.24
49-54	41	58.64	7	49.66	31	60.25	17	47.62	8	63.50	40	54.86
55-60	46	67.57	10	56.46	36	67.86	20	58.20	14	73.72	42	62.86
61-66	24	72.23	15	66.67	28	73.78	11	64.02	7	78.83	32	68.95
67-72	29	77.86	7	71.43	26	79.28	10	69.31	4	81.52	32	75.05
73-78	18	81.36	6	75.51	14	82.24	10	74.60	6	86.13	18	78.48
79-84	11	83.50	5	78.91	13	85.00	3	76.19	2	87.59	14	81.14
85-90	19	87.18	8	84.37	15	88.16	12	82.54	6	91.97	21	85.14
91-96	9	88.93	7	89.12	12	90.70	4	84.66	3	94.16	13	87.62
97-102	9	90.68	2	90.48	9	92.60	2	85.71	-		11	89.71
103-108	17	93.98	-		11	94.26	6	88.89	1	94.89	16	92.18
109-114	7	95.34	4	93.20	9	96.83	2	89.95	1	95.62	10	94.67
115-120	7	96.70	4	95.92	6	98.10	5	92.59	2	97.08	9	96.38
121-126	5	97.67	-		1	98.31	4	94.71	2	98.54	3	96.95
127-132	4	98.45	1	96.60	2	98.73	3	96.30	1	99.27	4	97.71
133-138	2	98.84	2	97.96	2	99.15	2	97.35	-		4	98.76
139-144	2	99.22	-		-		2	98.41	-		2	98.86
145-150	1	99.42	-		-		1	98.94	1	100.00	-	
151-156	2	99.81	-		1	99.37	1	99.47	-		2	99.24
157-162	1	100.00	2	99.32	3	100.00	-		-		3	99.81
163-168	-		-		-		-		-		-	
169-174	-		-		-		-		-		-	
175-180	-		1	100.00	-		1	100.00	-		1	100.00
Total	515		147		473		189		137		525	
Average	56.72		61.42		55.14		64.35		52.70		59.09	

TABLE 14.

Ages of 568 pedigree Jersey cows in relation to milk recording (M.R.), Tuberculin testing (T.T.), and homebreeding.

Age at calving (months)	M.R.		Non-M.R.		T.T.		Non-T.T.		Homebred		Non-homebred. British		Non-homebred. Island		Total non-homebred	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
19-24	19	4.22	2	1.69	12	3.19	9	4.69	9	2.68	10	7.63	2	1.98	12	5.17
25-30	88	23.78	20	18.64	76	23.40	32	21.35	82	27.08	22	24.43	4	5.94	26	16.38
31-36	27	29.78	8	25.42	27	30.59	8	25.52	25	34.52	8	30.53	2	7.92	10	20.69
37-42	66	44.44	16	38.98	58	46.01	24	38.02	53	50.30	13	40.46	16	23.76	29	33.19
43-48	37	52.67	13	50.00	29	53.72	21	48.96	26	58.03	11	48.85	13	36.63	24	43.53
49-54	44	62.44	10	58.47	39	64.10	15	56.77	34	68.15	5	52.67	15	51.48	20	52.16
55-60	31	69.33	9	66.10	26	71.01	14	64.06	25	75.60	5	56.49	10	61.38	15	58.62
61-66	28	75.56	8	72.88	23	77.13	13	76.83	16	80.36	12	65.65	8	69.30	20	67.24
67-72	18	79.56	3	75.42	13	80.58	8	75.00	9	83.04	9	72.52	3	72.27	12	72.41
73-78	18	83.56	6	80.51	11	83.51	13	81.77	12	86.61	7	77.86	5	77.22	12	77.59
79-84	16	87.11	2	82.20	9	85.90	9	86.45	12	90.18	3	80.15	3	80.19	6	80.17
85-90	13	90.00	5	86.44	12	89.10	6	89.58	5	91.67	7	85.50	6	86.13	13	85.78
91-96	10	92.22	4	89.83	7	90.96	7	93.22	6	93.45	2	87.02	6	92.07	8	89.22
97-102	9	94.22	4	93.22	8	93.08	5	95.83	5	94.94	5	90.84	3	95.04	8	92.67
103-108	4	95.11	-		4	94.15	-		2	95.54	2	97.37	-		2	93.53
109-114	4	96.00	6	98.31	7	96.01	3	97.39	2	96.13	7	97.71	1	96.03	8	96.98
115-120	5	97.11	1	99.15	5	97.34	1	97.91	4	97.32	-		2	98.01	2	97.84
121-126	5	98.22	-		3	98.14	2	98.95	3	98.21	1	98.47	1	99.00	2	98.71
127-132	4	99.11	-		4	99.20	-		3	99.11	1	99.24	-		1	99.14
133-138	-		-		-		-		-		-		-		-	
139-144	-		1	100.00	1	99.47	-		1	99.40	-		-		-	
145-150	2	99.56	-		1	99.73	1	99.47	-		1	100.00	1	100.00	2	100.00
151-156	1	99.78	-		1	100.00	-		1	99.70	-		-		-	
193-198	1	100.00	-		-		1	100.00	1	100.00	-		-		-	
Total	450		118		376		192		336		131		101		232	
Average	53.25		55.69		52.85		55.54		50.21		57.45		60.76		58.89	

TABLE 15.

Age distribution of 662 pedigree Ayrshire bulls at time of conception of their daughters in relation to tuberculin testing (T.T.), homebreeding, and country.

Age in months	T.T.		non-T.T.		Homebred		Non-Homebred		English		Scottish	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
10-15	47	9.13	17	11.56	18	22.45	46	8.01	10	7.30	54	10.29
16-21	89	26.41	25	28.57	17	39.76	97	24.91	25	25.55	89	27.24
22-27	90	43.88	20	42.18	16	57.94	94	41.29	29	46.72	81	42.67
28-33	53	54.17	20	55.78	14	73.84	59	51.57	18	59.85	55	53.14
34-39	60	65.83	18	68.03	9	84.06	69	63.59	17	72.26	61	64.76
40-45	44	74.37	11	75.51	3	87.47	52	72.65	8	78.10	47	73.71
46-51	38	81.75	7	80.27	1	88.61	44	80.31	8	83.94	37	80.76
52-57	29	87.38	11	87.76	1	89.74	39	87.11	8	89.78	32	86.56
58-63	17	90.68	5	91.16	1	90.88	21	90.77	2	91.24	20	90.67
64-69	11	92.82	3	93.20	-		14	93.21	3	93.43	11	92.76
70-75	9	94.56	2	94.56	2	93.15	9	94.77	1	94.16	10	94.67
76-81	4	95.34	2	95.92	2	95.42	4	95.47	1	94.89	5	95.62
82-87	6	96.50	2	97.28	-		8	96.86	2	96.35	6	96.76
88-93	4	97.28	-		1	96.56	3	97.39	1	97.08	3	97.33
94-99	4	98.06	-		-		4	98.08	2	98.54	2	97.71
100-105	1	98.25	-		-		1	98.26	-		1	97.90
106-111	3	98.84	-		-		3	98.78	-		3	98.48
112-117	3	99.42	2	98.64	2	98.83	3	99.30	1	99.27	4	99.24
118-123	-		-		-		-		-		-	
124-129	1	99.61	-		-		1	99.48	-		1	99.43
130-135	1	99.81	-		-		1	99.65	-		1	99.62
136-141	-		1	99.34	-		1	99.83	-		1	99.81
142-147	-		1	100.00	1	100.00	-		-		1	100.00
160-165	1	100.00	-		-		1	100.00	1	100.00	-	
Total	515		147		88		574		137		525	

TABLE 16.

Age distribution of 568 pedigree Jersey bulls at time of conception of their daughters in relation to milk recording (M.R.), tuberculin testing (T.T.), and homebreeding.

Age in months.	M.R.		Non-M.R.		T.T.		Non-T.T.		Homebred		Non-homebred British		Non-homebred Island		Total non-homebred	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
		-		-		-		-		-		-		-		-
10-15	43	9.55	10	8.47	36	9.57	17	8.85	20	15.27	27	7.99	6	6.06	33	7.55
16-21	74	26.00	17	22.88	63	26.33	28	23.44	23	32.82	58	25.15	10	16.16	68	23.11
22-27	79	43.55	21	40.68	68	44.14	32	40.10	21	48.85	57	42.01	22	38.38	79	41.19
28-33	62	57.33	23	60.17	55	59.04	30	55.73	19	63.86	50	56.80	16	54.54	66	56.29
34-39	53	69.10	19	76.27	40	69.68	32	72.39	12	72.52	48	71.01	12	66.66	60	70.02
40-45	35	76.88	9	83.90	29	77.39	15	80.20	11	80.92	22	77.51	11	77.77	33	77.57
46-51	26	86.66	4	87.29	21	82.98	9	84.89	5	84.73	19	83.14	6	83.83	25	83.30
52-57	17	86.44	5	91.53	14	86.70	8	89.06	5	88.55	16	87.87	1	84.84	17	87.19
58-63	16	89.99	4	94.92	9	89.10	11	94.79	5	92.37	11	91.12	4	88.88	15	90.62
64-69	14	93.10	2	96.61	12	92.29	4	96.87	3	94.66	10	94.08	3	91.91	13	93.59
70-75	5	94.21	1	97.46	5	93.62	1	97.39	-		3	94.97	3	94.94	6	94.97
76-81	6	95.55	1	98.31	4	94.68	3	98.95	2	96.18	4	96.15	1	95.95	5	96.11
82-87	8	97.32	1	99.15	8	96.81	1	99.47	3	98.47	4	97.34	2	97.97	6	97.48
88-93	5	98.43	-		5	98.14	-		2	100.00	1	97.63	2	100.00	3	98.17
94-99	3	99.10	-		2	98.67	1	100.00	-		3	98.52	-		3	98.86
100-105	1	99.32	-		1	98.94	-		-		1	98.82	-		1	99.08
106-111	1	99.54	-		1	99.20	-		-		1	99.11	-		1	99.31
112-117	1	99.76	-		1	99.47	-		-		1	99.41	-		1	99.54
118-123	1	100.00	-		1	99.73	-		-		1	99.70	-		1	99.77
124-129	-		1	100.00	1	100.00	-		-		1	100.00	-		1	100.00
Total	450		118		376		192		131		338		99		437	

PART II.

HERD SIZE AND ITS GENETICAL SIGNIFICANCE IN PEDIGREE CATTLE BREEDING.

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C O N T E N T S.

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There are several ways in which herd size may influence the results of selective breeding. A herd is in effect a small and partially or completely isolated sub-group of the whole cattle population, and although gene frequency within it is subject to the effects of selection and the immigration of stock bred elsewhere, accidents of gene sampling between one generation and the next will superimpose purely random fluctuations in the gene frequencies. Such fluctuations are one of the major difficulties of selective breeding, and their importance varies inversely as the numbers of breeding animals. The variance in gene frequency due to chance fluctuations is pq/2N, where p and q are the frequencies of a pair of alleles, and N the number of breeding animals weighted according to their reproductive importance (Fisher, 1930). Increasing values of N clearly diminish the variance due to accidents of gene sampling. In other words, gene frequency in a herd of 100 cows and 5 bulls is much less subject to sampling error than it is in a herd of 20 cows and 1 bull. Hazel (1943), discussing selection indexes, points out that few herds are large enough to provide sufficient data to make the sampling errors of the necessary genetic constants small.

Herd size also determines, to a great extent, the numbers of bulls in use as well as the number and rate of production of offspring by which sires may be judged.

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The rate at which they become available for the testing of their sires does not necessarily increase with herd size, depending as it does mainly on the number of mates allowed a sire per year, but the practicability of using a young bull freely for a period and then partially or wholly retiring him until he can be judged by results is greater in the large herd than in the small. In one- and two-sire herds, which are exceedingly common, it is hardly possible, under existing rates of replacement, to discriminate promptly against an unsuccessful sire by disposing of all his progeny. It may be supposed that many of them will have to be retained and their progeny in turn will be needed for replacements. Very little benefit can thus be obtained from the information about the original daughters. Even in the selection of bulls, it is the performance of the selected female ancestors which is usually emphasized rather than that of the half-sisters, and in any case only a minority of bulls are used in the herd in which they are bred. The same difficulties apply to large herds, but with the difference that it is easier to eliminate the ill effects of one of a number of sires.

To avoid close inbreeding and to prevent bulls of unknown breeding value from siring the greater part of the herd is a recurring problem in small herds, particularly the one-sire herds. The result is a strengthening of the tendency for bulls to be changed frequently/

frequently and disposed of before their progeny mature. Unless bulls in general are selected with much greater genotypic accuracy than seems at all likely, the series of bulls used will probably be of the gene frequency characteristic of the population from which they were drawn and hence the herds derived from them will tend to fluctuate about the average for that population.

From the point of view of securing performance data and eliminating from them the effects of disease, it would be a further disadvantage of the small herds if they found disease control and milk recording less attractive than the large herds as is suggested by Garner (1944), Hume (1942), and Donald (unpublished data). In Northern Ireland, the small size of herds and lack of isolation has made control of contagious abortion by hygiene ineffective (N.I.V.M.A., 1944).

If the existing theories regarding the effects of sampling on gene frequency and the value of progeny testing as an aid to selective breeding are accepted, small herds must be regarded as being handicapped. An attempt has therefore been made to determine approximately the herd size distribution in Britain of the principal pedigree stocks with a view to finding out how far the production of improved stocks by selective breeding is impeded by inadequate numbers.

The method of investigation has been to use direct information about herd size whenever it has been given in breed herdbooks, and failing that to deduce it from the/

the numbers of registrations of females. Inaccuracies are inevitable but unlikely to obscure the chief features of the size distributions. Wherever possible, data on births and herd sizes for 1939 have been selected. Herd size is to be understood as including females of all ages and excluding males. Where samples have been taken, the methods of selecting regularly spaced pages or letters of the alphabet have been used, but with some adjustment to allow for the fact that the initial letters of herd prefixes and owners vary in frequency according to country of origin. In a sense, all the data are based on samples since they refer to single herdbooks and therefore to a single year, and minor regional and breed differences shown by the average numbers of herdbook entries are therefore to be interpreted with caution. Non-pedigree and grading appendix cattle in pedigree herds are excluded.

Herd Size and Herdbook Entries of Females in the Jersey, Guernsey, Devon and Red Poll Breeds.

Certain herdbooks, principally those of the Guernsey, Jersey and Red Poll breed, publish lists of animals of all ages in breeders' herds at a given date. From these lists it is possible to obtain data on the size and composition of the herds in relation to the numbers of herdbook entries of individual animals made during the preceding year. Table 1, which shows the relation between the number of females entered in the herdbooks and the total breeding stock, is based on a sample of 200 Guernsey herds and on all listed Jersey and Red Poll herds.

TABLE 1./

TABLE 1.

Herdbook entries of females in relation to total females.
(1940 herdbooks)

Breed	Jersey	Guernsey	Red Poll	Devon
Total herds:				
Herds entering females in herdbook	564	200 *	273	245
Herds entering females in herdbook	473	154	220	177
Herds entering males only	5	5	2	31
Herds making no entries	86	41	51	37
Total females (all herds, all ages)	14,147	4,360	11,536	
Total females per herd:				
All herds	25	22	42	
Herds making entries	29	26	49	
Herds making no entries	5.5	4.5	13.4	
Females entered:				
As % of total females	19.6	20.2	17.7	
As % of all females in herds making entries	20.3	21.0	18.8	
Ratio female/male entries (herdbook totals)	6.9	4.3	6.7	1.6

* Sample

No herd lists are given in the Devon herdbook so that the number of females in each herd cannot be obtained. Unlike most other present-day herdbooks, however, Davy's Devon herdbook records birth notifications from which presumably nearly all herds with at least one cow calving during the year can be recognised along with their herdbook entries. Although the classification of herds is not therefore on quite the same basis as that of the other three breeds, there is little doubt that a comparatively large proportion of Devon herds enters males but no females in the herdbook and that it does so because there is a low overall ratio of females to males entered and because herd size tends to be small (as will be shown later).

In all four breeds 15-20% of the herds made no entries at all. These are mainly very small herds, although in the Red Poll breed a number of comparatively large herds were found without entries for the year. In most breeds the number of such herds cannot easily be obtained so that it is important to observe what difference it makes to average herd size when they are excluded from the calculation. In each case shown the average becomes about one-sixth too great.

Numerous as they are, herds without entries do not contribute much to the total breeding stock, and therefore when they are excluded the relation between numbers of female herdbook entries and total females is little changed. Table I shows that in the three breeds/

breeds mentioned the former is about 20% of the latter. Obviously if this relation holds for all breeds, the total number of females and herd size for each can be obtained by multiplying total and average female herd: :book entries by 5. Herd size, however, both within and between breeds, varies, so that it is desirable to determine whether the factor 5 is applicable to herds of all size groups. This has been done in Table 2, herds without entries being included in their appropriate size groups.

TABLE 2/

TABLE 2.

Ratios of Herdbook Entries of Females to Total Females according to Herd Size.

Herd Size (excluding bulls)	Guernsey		Jersey		Red Poll	
	Herds	Ratio	Herds	Ratio	Herds	Ratio
1 - 5	49	0.11	106	0.15	23	0.12
6 - 10	37	0.20	106	0.19	25	0.14
11 - 15	20	0.19	65	0.18	36	0.14
16 - 20	18	0.17	54	0.20	19	0.22
21 - 25	21	0.21	48	0.20	19	0.18
26 - 30	12	0.20	33	0.19	19	0.19
31 - 40	11	0.22	46	0.19	29	0.16
41 - 50	11	0.19	29	0.22	28	0.18
51 - 60	4	0.18	30	0.19	20	0.17
61 - 100	13	0.22	34	0.20	29	0.19
101 -	4	0.21	13	0.20	26	0.18
Total	200	0.202	564	0.196	273	0.177

With the exception of the smallest herds, there seems to be a uniform policy with respect to registration of heifers in herds of all sizes. The lower rate of registration in small herds results mainly from the absence in some of them of a bull of the same breed, and in others from a very recent founding with purchased stock. The lower rate of the Red Polls may be due to a higher age at first calving than obtains in the Channel Island breeds, and consequently a rather greater proportion of young unbred stock.

Since the actual sizes of herds in these three breeds are known, it is possible to compare their observed distribution with that calculated from the herdbook entries of females made by the same herds and multiplied by 5. This is done in Table 3. Estimated herd sizes naturally differ by multiples of five and each has been regarded as the mid-point of the groups into which the actual sizes have been divided. In order to condense the data, larger groupings have been made which account for the classification of herd size shown in the Table.

TABLE 3/

TABLE 3.

Estimated and Actual Distributions of Size of Herds making one or more Herdbook Entries of Females.

Herd Size (total ♀♀)	Jersey		Guernsey		Red Poll	
	Actual	Estd.	Actual	Estd.	Actual	Estd.
1-12	158	167	50	54	30	29
13-22	104	102	39	36	37	46
23-32	73	61	24	20	35	38
33-42	42	44	13	11	26	18
43-52	25	21	10	11	22	25
53-102	58	63	14	17	47	46
103-152	8	8	4	4	15	10
153-202	3	6	-	1	4	5
203-252	2	1			2	1
253-	-	-			2	2
Total:-	473	473	154	154	220	220

The agreement between the actual and estimated distributions is as good as can be expected. The former itself will vary with the time it is taken, and absolute agreement would not necessarily show great accuracy of estimation. It is therefore considered justifiable to proceed with the method of estimating herd size in other breeds of which the actual sizes are not known. It is unfortunate that direct data have not been found for a greater variety of breeds including especially a pure beef breed, but in the light of such information as there is about the replacement rates of pedigree dairy and beef cattle (Smith & Robison, 1931), it may be assumed for present purposes that the distribution of herd size can be found from herdbook entries of all breeds. For the individual herd, of course, this process would often lead to very inaccurate results, but it will be applied only to whole breeds or large samples.

These considerations raise the question as to what should be regarded as a pedigree breeding herd. Logically, the smallest herd would consist of a single registered calf, but to adopt such a definition is not only impracticable with the information available, but also misleading.

From a genetical point of view it is important to know the extent to which the actual and possible techniques of selective breeding are affected by the numbers of animals available in herds. Herds which consist/

consist of only a few animals, although numerous, can hardly be considered significant in this respect. The total animals of which they dispose is relatively small and it is proposed to disregard the bulk of them by considering as herds only those which enter at least one animal in the herdbook year selected for study. As may be seen from Table 1, there are many small herds which do not fall within this definition. Although these herds as a group can hardly make much steady progress by selective breeding, they have some importance to the larger herds as purchasers, and to commercial herds as multipliers of pedigree stock. The vagaries of the sex ratio will result in the exclusion of some herds which in another year would be included, but as this works both ways, the average values obtained for herd size should not change much from year to year. Another point which should be mentioned is that some of the herds excluded because of no entry are of moderate size but so newly established that there has been no time for the birth and entry of young stock.

Estimation of Devon and Hereford Herd Size from Birth Notifications.

In Davy's Devon Herdbook for 1939 the birth notifications by 244 breeders are recorded. Among them they notified 1001 bull and 1075 heifer calves. This suggests that some bull calves are not notified, and consequently doubling the number of heifers probably/

probably gives a better indication of total calvings. Dividing by the number of breeders yields a herd average of 8.8 calves of both sexes for the year. Assuming that the total herd size is double the number of cows (see below), the average herd size in the Devon breed becomes about 18. This is close to the estimate of 20 arrived at in Table 7 by multiplying the heifer herdbook registrations by 5.

Owing to the nature of the herdbook, the figures obtained for the Hereford breed are not quite comparable with those of the other breeds. Hereford calves appear first in the herdbook as cow produce and many calves are so entered even though they are recorded as dead or steered. Consequently the number of heifer calves noted as entered by individual breeders (and hence the estimated herd size) is probably slightly higher than would have been found by the usual method. Herdbook entries of dead or steered animals are not confined to the Hereford breed.

From a sample of the cow produce entries of the 1939 herdbook, the data in Table 4 were obtained.

TABLE 4/

TABLE 4.

Cow Produce and Herd Size in Pedigree Hereford Herds.
(1938 births)

		England	Wales	Eire
Total herds in the sample:-	...	107	49	218
(a) notifying females	...	100	45	132
(b) notifying males only	...	7	4	86
No: of calves notified:-				
Bulls	...	754	151	345
Heifers	...	894	189	287
Twin pairs	...	47	10	5
Estimated total calvings	...	1840	390	700
Calvings per herd	...	17.2	8.0	3.2
x 2 for average herd size	...	35	16	7
Heifers notified per herd	...	8.8	4.1	1.3
x 5 for average herd size	...	44	21	7

Two methods of arriving at average herd size have been used in Table 4, one based on twice the total calvings (estimated by doubling the number of heifers (bulls in Eire), adding the number of twin pairs, and rounding the result), and the other on five times the number of heifers notified. Whereas in England and Wales more heifers than bulls were notified, the reverse occurred in Eire. Since the sex ratio is likely to be much the same in all breeding areas, it would seem proper to judge herd size in Eire by doubling bull entries rather than the heifer entries to obtain the total calvings. While the results for Irish herds are the same, they differ for the English and Welsh herds. The discrepancy may arise either because calved cows are less than half the total females, or because the ratio of heifers up to a year old to total females is between 1/4 and 1/5 rather than 1/5. Both causes may be at work, so that the real average herd size, allowing for sampling error, may lie between the two estimates. The pair of Eire estimates are similar because the estimate based on heifers notified does not take into account the shortage of numbers in that category, and to that extent the estimates are too low. The data for all three countries exclude herds which, on account of size, or other reason, notified neither bulls nor heifers. Since these will in general be the smallest herds, all estimates will tend to be too high. It seems sufficiently clear, nevertheless/

nevertheless, that the average Hereford herd in England is of the order of 20 cows, in Wales of 10 cows and in Eire of 3 cows (excluding in-calf heifers).

The Proportion of Pedigree Cows in the Total Population.

The total entries of females for practically all breeds in Great Britain, N. Ireland and Eire during 1938 was about 48,700 (Donald, 1944). Deducting those estimated to come from N. Ireland or Eire, the number from England, Scotland and Wales becomes 45,600. The total population of pedigree females, about five times as great, would have contained some 228,000 cows and heifers of all ages, approximately half of which would have been calved cows (including heifers). In the official agricultural statistics for 1938, it is disclosed that on June 4th there were 3,035,000 cows in-calf or in-milk in Britain, so that pedigree cows contributed about 3.5 - 4.0% of the total. This may be compared with the corresponding estimates for bulls of 30-37% and 54-68% for England and Wales, and Scotland, respectively (Donald, 1944). In the U.S.A. about 5% of the dairy cattle are purebred (Alsop, 1944). Herdbook sows, according to Haring (1943), form only 5% of the total sow population in Germany, and herdbook boars 18%.

In making the above estimate of the proportion of pedigree cows in the total cow population, it has been assumed that in the pedigree stocks half the females are/

are cows which have calved and half heifers which have not. This is admittedly a rough approximation to what is a very variable quantity, so that some justification is needed.

In the herd lists of the 1940 Jersey herdbook, 570 herds are detailed in which there were 50% cows (including heifers in-milk), 44% heifers and young female stock, and 6% bulls of all ages. Of the females, rather more than half would appear to be calved cows and heifers, but if allowance is made for non-breeding and recently established herds, the assumption of 50% may not be far wrong. Where it is customary to adopt a somewhat later age at first breeding for heifers than applies to Jerseys, the proportion of calved cows may be less than half. This may account at least to some extent for the general position among Scottish dairy cattle which are predominantly Ayrshire and mainly kept in breeding herds. Here, as may be deduced from the official figures for 1938, about 47% of all females were cows in-calf or in-milk, and 53% heifers in-calf or young stock.

Breed and Regional Variation in Average Numbers of Herdbook Entries of Females and in Herd Size.

The average numbers of heifers entered by herds of the different breeds and countries (Table 5) are based on total heifer entries divided by the total number of herds/

herds entering at least one bull or heifer in the herdbook. It will be perhaps somewhat easier to relate the observed differences to farming conditions if reference is made to Table 6, which has been compiled from Table 5 by multiplying the entries by 5. By so doing a source of error has been introduced, which may exaggerate or obscure breed differences. In so far as breeding management is similar for a particular breed in the various countries, regional differences should be less affected. The appropriate figure for the various breeds might vary between 4.5 and 5.5, but adequate information is lacking on this point. The late maturing breeds in particular may be penalized by using 5, but if the calved cows of such breeds/

<u>TABLE 5/</u>

TABLE 5.

Average herd registrations of pedigree females by breeds and Countries.
(Number of herds making one or more herdbook entries in brackets.)

Breed	England	Ireland	Scotland	Wales	Remarks
Shorthorn	6.8 (541)	1.9 (349)	7.2 (45)	3.7 (57)	Sample
Lincoln Red	9.2 (122)				
Red Poll	9.1 (222)				
Welsh Black	8.0 (4)			3.3 (85)	
South Devon	4.7 (102)				
Kerry		4.1 (20)			
Ayrshire	12.3 (86)	2.5 (15)	15.1 (329)		Sample
British Friesian	6.5 (546)	4.2 (29)	8.8 (64)		Sample
Guernsey	5.5 (159)				Sample
Jersey	5.8 (478)	3.1 (37)	3.0 (13)		
Aberdeen Angus	5.8 (101)	1.1 (391)	4.9 (283)		Sample
Galloway	3.7 (42)	1.3 (33)	5.9 (98)		
Devon	3.9 (208)				
Sussex	6.1 (43)				
Hereford	8.8 (107)	1.3 (218)		4.1 (49)	Sample

Except where samples were taken, all available herds were used including herds registering males but no females.

Hereford data are not exactly comparable. See text.

TABLE 6.

Estimated average herd sizes (females of all ages) by breeds and countries.

Breed	England	Ireland	Scotland	Wales
Shorthorn	34	10	36	19
Lincoln Red	46			
Red Poll	46			
Welsh Black				17
South Devon	24			
Kerry		21		
Ayrshire	62	13	76	
British Friesian	33	21	44	
Guernsey	28			
Jersey	29	16	15	
Aberdeen Angus	29	6	25	
Galloway	19	7	29	
Devon	20			
Sussex	31			
Hereford	44	7		21

breeds have a longer productive life than those of the earlier maturing types, the balance between calved and uncalved stock should be at least partly righted. The discrepancy between the estimated herd size for Red Polls of 46 and the actual 49 (see Table 1) is probably indicative of the error involved.

Irish and Welsh herds consistently make comparatively few entries. The pedigree portions of their stocks must be correspondingly small, and the explanation is no doubt largely to be sought in the prevailing size and fertility of holding.

Ayrshire herds are notably larger than those of any other breed, both in Scotland and England. They may become yet larger in England, for the 1939 average is probably depressed by the presence of numbers of newly established herds which have not been built up to full strength. New herds are of course arising continually in all breeds, but those which are expanding in total numbers such as the Ayrshire and Friesian would be most affected. Just why the Ayrshire herds should be so much larger than others is not clear. The best suggestion that can be offered at present is that it is a specialist breed which is kept on farms where dairying is the main occupation. They may also be popular in areas characterised by level milk production and grassland farming which, according to Bridges (1943), lead to larger herds than does seasonal production and arable/

arable farming. If the assumption that 20% of an Ayrshire herd is composed of heifers registered during the year were too low, herd size would be over-estimated, but even if the actual figure was 22% the estimate for Scottish herds would still be as high as 69 females. Paterson (1943) reports that 37,939 cows were herd-tested in 805 Scottish herds in 1942, an average of 47 cows per herd. This overstates herd size to the extent that replacements for cows disposed of during the year are also tested. If the average productive lifetime of a cow is three years, the true herd size would be about 36 cows, or 70-75 females of all ages. If the productive lifetime is longer than three years, herd size would be correspondingly larger.

So far, the breeding of pedigree Ayrshires in England does not seem to have been undertaken by the small herd owner to the same extent as with Friesians. In those breeds with widely used grading-up schemes such as the Shorthorn and Friesian, many herds will be only partly pedigreed and therefore depress the estimate of herd size.

Where mixed farming is the rule, beef and dual purpose breeds are not only of limited or even minor importance in the farm economy, but also have to share the resources in foodstuffs with non-reproductive stores or fatstock, and often with a high proportion of young bulls (Donald, 1944). The breeding herd might/

might therefore be expected to be smaller than in the specialist dairy breeds. Until more is known of the geographical distribution of pedigree herds in relation to farm practice, however, not much progress can be made towards an explanation of the differences between breeds with the same general purpose.

Variation in Herdbook Entries and Herd Size within Breeds.

A pedigree herd may vary in size from 1 to over 400 animals. The maximum numbers of heifer entries found were 110 from an English Shorthorn herd, and 121 from a Scottish Ayrshire herd. Such large herds are unusual and the majority of herds are smaller than the averages given in Table 6. This can be seen from the cumulative percentage distribution of herd size according to numbers of female herdbook entries which is presented in Table 7.

The number of females of all ages in a herd has been halved at the bottom of the Table to indicate roughly the number of calved cows or mates available for the bull or bulls. Young stock are part of the breeding material in the sense that they provide some of the information and surplus on which selection can be based. They do so no doubt to a very variable extent, so that it is probably more useful to compare herds on the basis of numbers of bulls' mates. Many of these calved cows will not calve again but they will be replaced by an equal number of bred heifers.

TABLE 7/

TABLE 7.

Cumulative percentage distribution of herd size based on numbers of herdbook entries of females in 1939, and limited to herds entering at least one male or female.

Breed	Number of females entered in herdbook.												No. of herds in	
	0	1-2	3-4	5-6	7-8	9-10	11-15	16-20	21-30	31-40	41-50	51-	Sample	Breed [b]
Ayrshire	4	15	26	34	40	46	62	75	90	96	98	100	791	790
British Friesian	7	40	59	67	75	81	90	95	97	99		100	542 c	1270
Guernsey	3	37	60	72	79	86	92	97	99	100			159	(520)
Jersey	1	36	57	70	79	84	94	97	99			100	478	480
Shorthorn														
England	6	33	51	65	73	80	90	96	98	99		100	540 d	(1120)
Ireland	26	78	91	94	96	98	99	100					349	(770)
Scotland	4	22	47	58	60	73	91	100					45	(100)
Lincoln Red	7	20	32	50	61	70	80	87	97	100			122	120
Red Poll	1	15	35	52	60	71	85	92	96	99		100	222	230
Welsh Black	19	54	75	86	92	94	99	100					85	90
South Devon	9	37	55	78	81	89	97	100					102	100
Galloway	3	29	53	74	82	89	96	99	100				140 e	170
Sussex	7	30	49	65	86	91	95			100			45	45
Devon	15	50	71	85	89	93	98	99	100				208	210
Aberdeen Angus	15	44	58	71	80	85	95	98	100				386	480
Ireland a	17	83	92	95	97	98	99	100					391	860
Hereford														
England	7	26	41	50	56	66	87	91	99		100		107	200
Wales	8	51	77	82	90		96	100					49	110
Ireland a	22	83	93	95	98	99	100						218	500
Approx.														
Herd size - up to		10	20	30	40	50	75	100	150	200	250	255-	4979	8165
No. of cows - up to		5	10	15	20	25	38	50	75	100	125	126-		

a .. distribution based on numbers of males entered in herdbook.
b .. actual or estimated ( ) total number of herds making at least one entry in 1939 in rounded numbers.
c .. English herds only.
d .. excluding Welsh herds. e .. excluding Irish herds.

Because more bulls than heifers were entered by Irish Aberdeen Angus and Hereford herds, the size distribution for them has been based on numbers of bulls instead of heifers. This greatly increased the number of herds in the samples but actually made little difference to the percentage distribution.

In most breeds half, and sometimes much more than half the pedigree herds (in the present restricted sense) consist of some 10-12 or fewer cows. In Ireland, it seems likely that about 90% do so. The principal exceptions are the Ayrshire (including English and a very few Irish herds), Lincoln Red, Red Poll, and Hereford (English herds) breeds where from 26 to 41% of the herds are in this class. Raising the limit to about 20 cows takes in about 75% or more of the herds in all breeds except the same four and the Scottish herds of Shorthorns. In these it takes in about 40% of the Ayrshire herds and rather more than half of the others. Herds of more than about 50 cows are very scarce in most breeds. Once again these four breeds are exceptional, the herds in this class compris:
:ing 25%, 13%, 8% and 9% of the totals respectively.

The last two columns of Table 8 give the numbers of herds used in calculating the percentage distribut:
:ion, and for comparison the actual or estimated total number of herds (in rounded numbers) making entries of either males or females in the various herdbooks during the year. Adding to the latter the herds in small breeds/

breeds not shown in the Table, and those making no entries, the total number of active pedigree breeding herds in the four countries probably does not exceed 8500-9000. More than 2150 of them are in Ireland. As may be calculated from the data in the Table, the remaining 6000-7000 include about 420 which are of 50 cows or more. About 200 of these would be Ayrshire herds, and the rest distributed among 13 other major breeds.

The data of Table 7 have been condensed and presented graphically in Fig. 1. Only five size classes are shown, namely 0-2, 3-4, 5-10, 11-20 and 21 or more herdbook entries of females, and their frequency has been expressed as a percentage of the sample total. The breeds are arranged in order of the proportion of herds in the lowest size class. To show the varying numbers of herds in each breed, the width of the band allotted has been made proportional to the total number of herds as given in the last column of Table 7. The size classes can be thought of in terms of numbers of cows by multiplying the number of entries by 5/2. As might be expected, when the proportion of herds in the lowest size class increases, the proportion in the largest class diminishes. It could be otherwise if the increase in the former took place only at the expense of one or other of the two intermediate classes. As it is, however/

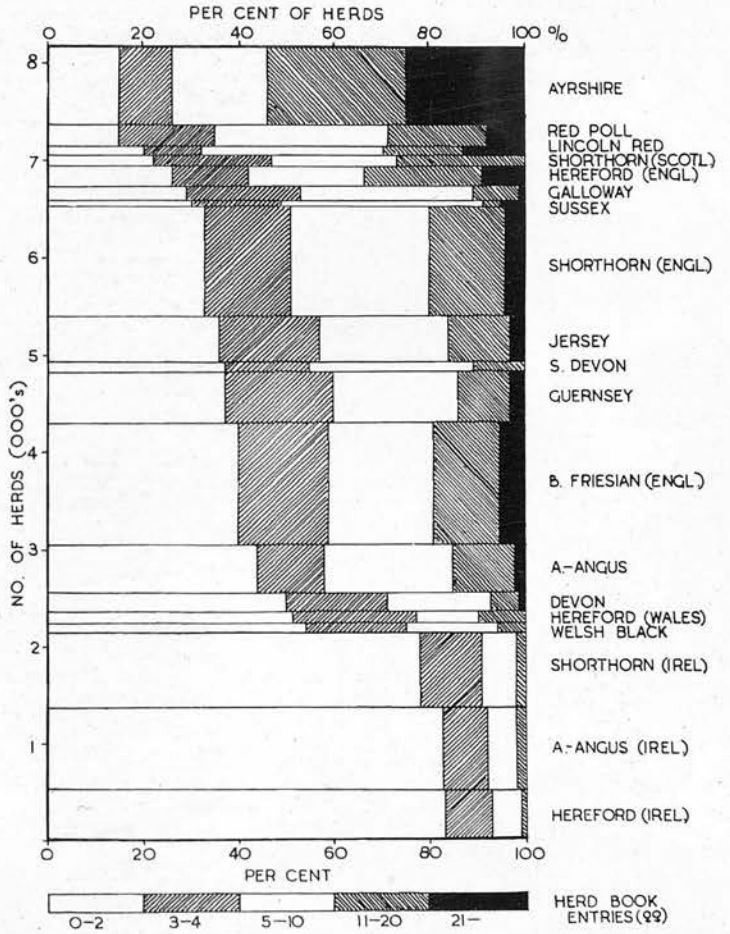
however, the factors favouring the occurrence of small herds militate against the occurrence of larger herds of all sizes. Generally speaking, the breed distributions of herd size are unimodal but vary considerably in range and in the position of the mode.

The graph shows clearly that the big majority of pedigree breeders in all breeds except the Ayrshire produce no more than 0-10 pedigree heifers per year.

FIGURE 1./

FIGURE I.

Percentage distribution of pedigree herds according to number of females entered in herdbooks during 1939. Breeds are arranged in order of the proportion of herds entering 0-2 females. Only those herds which made at least one entry of a male or female are included.



More than 50% of those making entries from herds in England and even greater proportions of those in Wales and Ireland are limited to 0-4 entries. Since most entries are made during the first year after birth, the number of animals annually reaching the age for breeding and trial must be smaller still. In large herds where only a nucleus of pedigree animals is kept, and in beef herds where surplus males are reared, there may of course be more material than this by which to judge breeding results.

Geographical influences are very apparent. They seem to govern herd size distribution far more than does the purpose for which the animals are kept. There are no very striking differences for instance, in the distributions shown for the Hereford, Shorthorn, and Friesian breeds in England; or between the Guernsey and Aberdeen-Angus (which includes both Scottish and English herds since they are very similar in size). Some differences according to purpose might have been expected since the land, labour, and management appropriate to beef, dual-purpose, and dairy breeds are not the same. Any effects which these might have on herd size would appear to be overridden by other factors which may include the influence of a market for bulls on land utilization, personal fancies for a particular breed, mixed herds, and so on.

It will be observed that the transition between the/

the Ayrshire and English Shorthorn is marked by the small English breeds (except the Devon and S. Devon) together with the Shorthorn herds in Scotland and the Galloway herds in South-West Scotland and North-West England. Each of these small breeds has a restricted geographical distribution and it seems likely that their characteristic herd size distribution is a reflection of farming conditions in those areas, especially size of holding and market for bulls. It may be worthy of note that apart from the Red Poll, these breeds are primarily concerned with the breeding of bulls for beef production and use a high proportion of their cows for the purpose. The Devon breeds, like the Welsh Black, appear to have few if any large herds devoted to pedigree breeding, a circumstance which is no doubt due to the nature of their ecological niche. There would appear to be no large-scale beef enterprises of the kind found overseas so it is not surprising that in some countries British breeds have been encouraged to develop local types adapted not only to the change of soil and climate but to management also. Where repeated importations are deemed necessary to counter the tendency to deteriorate, local conditions may well be setting up a selection pressure opposed to that operating in Britain.

Comparison with other Data.

Unlike the material now presented, distributions of/

of herd size obtained in other investigations are usually based on actual cow numbers, and comparison of results is made difficult by the inclusion of non-breeding herds (as in census data), and the use of size classes with different limits. The attempt is nevertheless made since certain broad differences can be seen. A condensed version of some published data will be found in Table 8 along with similar data on pedigree herds for certain representative British dairy breeds. Whilst the Jersey figures are based on the actual numbers of cows and heifers in-milk as given in the herd lists, the figures for the other breeds are estimated as closely as possible from the herdbook entries.

TABLE 8/

TABLE 8.

Percentage Distribution of Herd Size in Certain British Pedigree Breeds compared with data from Cambridgeshire, New Zealand, and the U.S.A.
(E = English herds only.)

Source	No. of cows	%	No. of cows	%	No. of cows	%
New Zealand	1-9	23.5	10-19	12.5	>19	64.0
United States	1-9	77.6	10-19	17.7	>19	4.7
Cambridge	1-10	81.6	11-20	11.7	>20	6.7
Shorthorn (E)	1-9	45	10-19	24	>20	31
British Friesian (E)	1-9	52	10-19	20	>20	28
Ayrshire	1-9	21	10-19	16	>20	63
Jersey	1-9	53	10-19	23	>20	24

For Cambridgeshire the data were secured in the course of a survey of dairy cows (Edwards, 1941); for the U.S.A. they were based on a census of herds selling milk (Hoard's Dairyman, 1942); and for the North Island of New Zealand they were based on herds selling dairy produce to dairy companies (Hume, 1942). It is not easy to be sure that such comprehensive figures are comparable with each other; they are certainly not directly comparable with the breed distributions shown. It is clear, however, that New Zealand dairy herds tend to be larger than those in the United States. According to the 1939 census in the U.S.A., 77.6% of the herds selling dairy products were of 1-9 cows and a further 17.7% of 10-19 cows. Only 4.7% of the herds were of 20 or more cows. These figures point to a much smaller average size than has been found for English and Scotch pedigree herds, but a census will include many small herds that would be unaccounted for in any less comprehensive survey. The Cambridge survey which took account of all dairy cows in the County, gives results very similar to the U.S.A. census. Both distributions may be expected therefore to show an excess of small herds as compared with the pedigree data which, as previously explained, exclude 15-20% small herds entering no animals during the year. In some breeds such as the Devon these small herds if taken into account might well reduce the average herd size to the Cambridgeshire level, but with/

with most breeds (including those specified in Table 8) this is improbable. So few pedigree Ayrshire herds make only one or two entries that it can be assumed that only a negligible number make no entries. Consequently the percentage distribution shown is probably close to the actual and very like that found in New Zealand. Small herds of Shorthorns, Friesians and Jerseys making no entries may comprise up to 20% of all pedigree herds and the inclusion of these would substantially increase the size of the class of herd with 1-9 cows to a figure more nearly approaching that found for Cambridgeshire. It has to be remembered, of course, that the latter is based on herds of 1-10 cows, and that it may not be typical of the regions from which the pedigree herds were drawn. These considerations can, however, hardly set aside entirely the excess of larger herds shown by the pedigree distributions. On the whole, it may be concluded that although most pedigree breeders work on a small scale it is probably not quite as small as that typical of many part-time commercial dairy farmers.

DISCUSSION.

The distribution of herd size is very pertinent to the question of livestock improvement. Within the registered stocks of the pure breeds from which the initial progress in selective breeding is expected, the majority of herds have been shown to fall within the limitations of 1-20 cows. The progeny of such herds, less than ten in number each year, can only be regarded as offering very inadequate material with which to arrive at a judgement of breeding value in respect of numerous and complicated characters. With few exceptions the cows in these small herds are mated to what is almost a random sample of one or two bulls. The resulting progeny are inevitably scattered in time of birth, and subject to varying seasonal influences on growth and development, so that an evaluation of their performance from the sire's point of view is complicated. By the time their performances are available in sufficient numbers, the sires have usually disappeared to make way for others which are unrelated. This may sometimes be unfortunate for the breeder, but is perhaps less of a loss to the breed since a sire capable of improving the performance of the only herd in which he has been used is still unproven with respect to his usefulness under other conditions and other levels of performance. Success within a herd does not necessarily qualify a bull either for inbreeding or for use in any other herd.

In/

In avoiding close inbreeding, breeders with small herds are usually right because the genetic merit of their herds and the information about the animals in it are usually insufficient to justify the risk. A gradual approach to the problem of limiting genetic variability and increasing relationship to desirable ancestors by means of purchased sires which are at first distantly related and later more closely related may be theoretically wise, but many small herds do not last long enough to carry it far and of the others some, perhaps many, will meet failure on the way. If more bulls were kept, close inbreeding could be avoided, but the time within which they could be safely judged would be rapidly lengthened unless they were used on all or nearly all the cows in their first year and then kept idle. The progeny testing of bulls in such herds is obviously very difficult.

The effect of a rapid sequence of unrelated bulls is to break down genetic isolation. Differences in gene frequency between one herd and another come to depend largely on the results of sampling - both bull sampling and gene sampling at meiosis. The former may not be quite random but the latter is. While the present scarcity of tested sires continues (and it may be expected to continue for a long time), most herds cannot hope to be much more than random samples of the breed to which they belong. Herds will show deviations from the breed average in genetic merit, and/

and the smaller the herd the greater these deviations may be in either direction, but they will have little permanence. The present methods of selecting sires are not likely to alter this. In New Zealand, where bulls are chosen as here with varying degrees of success, the sire survey work of Ward (1942) shows that the average sire left daughters of almost exactly the same production as their dams.

If most of the small herds are ruled out as being seriously hindered by the limitations of their size in constructive breeding, this task devolves upon a very few breeders who are not necessarily interested in it and prepared to take the trouble. The work of those who are will be swamped by the breed as a whole unless it is extended and maintained by other breeders. Further, breeders of pure but non-registered stock who have been using pedigree sires will have nothing to gain from the average pedigree bull since their stock will be genetically the same (cf. Candy <u>et al</u>. 1943). The difficulty of using the material in small herds for constructive breeding has long been felt in Denmark where about 92% of the herds consist of less than 15 milk cows, and has been met by the development of local cattle breeding societies and the public owner:
:ship of herdbooks. By these means, the detailed system of judging, progeny-testing, and recording of performance data is integrated (Larsen, 1935). This solution/

solution arose from a consciousness of the problem and is appropriate to the character of Danish farmers and farming. Other solutions may well be desirable for other circumstances, but cannot be replaced by techniques. Artificial insemination, for instance, offers an alternative to the communal bull, but not, if regarded merely as a technique, to the basic problem. Meanwhile, the tendency to regard individual herds or even individual animals as the significant units in animal improvement would appear to have little to recommend it either statistically or genetically. In his study of the Red Poll breed, Kislovsky (1940) remarks upon the small herd size (although as shown above it is comparatively large), limited progenies and youthfulness of sires, and the impossibility of organizing adequate linebreeding programmes whilst independent methods of breeding and selection are carried out in so many small units. He contends that breeding plans should embrace whole breeds; this is agreed provided it is understood that such plans allow for regional differences in environment and function within breeds. As has been shown by studies on natural populations the trend of evolution is governed mainly by the size of the interbreeding population, the degree of genetic isolation, and the amount of effective selection acting on the store of genetic variability (Wright, 1942). An appreciation, therefore, of the size, distribution, and organisation of/

of breeds of domestic animals would pave the way to the development of breeding methods that would be genetically sound and would co-ordinate the numerous individual efforts at present dissipated.

SUMMARY.

The average numbers of females of all ages (herd size) in pedigree herds of Jerseys, Guernseys, and Red Polls in 1939 were found to be 25, 22, and 42 respectively. Of the herds listed, 15-20% made no herdbook entries and were of much smaller than average size. Excluding these, the average numbers become 29, 26, and 49. The number of females entered in the herdbook during 1939 was about 20% of the total number of females of all ages. The same proportion was found in all herd size groups except the smallest where it was lower. As a general guide, therefore, to breed and regional differences in herd size in all the major breeds, the average number of herdbook entries of females has been multiplied by 5.

It is estimated that about 3.5 - 4.0% of all cows in-calf or in-milk (including heifers in-milk) in England, Scotland, and Wales combined are pedigreed.

A comparison of estimated pedigree herd sizes indicates that Irish herds of Shorthorn, Aberdeen Angus, and Hereford cattle are very small, averaging 10 or fewer females of all ages. Welsh herds of Herefords, Shorthorns and Welsh Blacks averaged about 20 females. The largest averages were found in Scottish Ayrshires (76), English Ayrshire (62), Lincoln Red (46), and Red Poll (46) herds.

The percentage distribution of herd sizes within breeds/

breeds shows a large preponderance of small herds. Probably 90% of the Irish and more than half of the herds elsewhere consist of less than 12 calved cows and heifers. It is estimated that there are only about 420 pedigree herds which contain 50 or more calved cows and heifers and that some 200 of these are Ayrshire herds. The total number of actively breeding pedigree herds in 1939 was about 8500-9000 of which 2150 were Irish.

Comparison with other data suggests that making allowance for the very small herds excluded from these calculations, the size of pedigree herds is a little larger than that of non-pedigree herds.

It is concluded that a very large proportion of all pedigree breeders are affected by the limitations of the small herd, chiefly enforced outcrossing and frequent bull-sampling, random fluctuations in gene frequency, and the difficulty of applying adequate progeny testing. In order to minimise these draw:
:backs and to co-ordinate the presently independent and conflicting policies of individual breeders, it is suggested that breeding plans should embrace whole breeds or localized subdivisions of breeds.

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PART III.

HERD SIZE IN RELATION TO MILK RECORDING AND TUBERCULIN TESTING IN PEDIGREE HERDS.

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CONTENTS.

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Both in Scotland and in England, the milk recording of small herds creates problems of expense and organization, for they not only cost relatively more to test but make it difficult to arrange the recorder's time most efficiently. The opportunity has been taken, therefore, of noting where it is possible, the practice of recording, so that it might be considered in relation to the size of pedigree herds. At the same time, those herds which tested for tuberculosis were also noted. In a previous discussion of the ages of cattle it was suggested that in the Jersey breed, milk recording and tuberculin testing were not only practised more commonly among large herds, but were also likely to be practised together. In order to test these suggestions more fully, the Jersey data have been re-arranged, and other data relative to the Guernsey and Dexter breeds added to them. The investigation has been limited to these three breeds since they are the only ones for which the necessary information could be obtained, their herdbooks stating whether each herd was tested and recorded or not.

All available Jersey and Dexter herds have been included, but only a sample of 200 Guernsey herds.

The analysis of the data is summarised in Table 1.

Herd Size.

The distributions of herds by size are similar in the Jersey and Guernsey breeds, except for rather more small/

TABLE 1.

Herd size in relation to tuberculin testing and milk recording in pedigree herds.

GUERNSEY (200 herds) 1939.

Herd Size ♀♀ of all ages	Total herds No.	Total herds %	No. of Herds TT MR	TT NMR	NTT MR	NTT NMR	TT	NTT	MR	NMR
1 - 10	86	43.0	6	7	17	56	13	73	23	63
11 - 20	38	19.0	13	4	8	13	17	21	21	17
21 - 30	33	16.5	15	1	10	7	16	17	25	8
31 - 40	11	5.5	8	1	2	-	9	2	10	1
41 - 50	11	2.0	5	-	3	3	5	6	8	3
51 - 60	4	2.0	2	1	1	-	3	1	3	1
61 - 70	6	3.0	3	1	1	1	4	2	4	2
71 - 80	3	1.5	1	-	2	-	1	2	3	-
81 - 90	2	1.0	2	-	-	-	2	-	2	-
91 - 100	2	1.0	1	1	-	-	2	-	1	1
100	4	2.0	2	-	1	1	2	2	3	1
Total ..	200	100	58	16	45	81	74	126	103	97
Observed %			29	8	22.5	40.5	37	63	51.5	48.5
Expected %			19.1	18	32.5	30.6				

JERSEY (564 herds) 1940.

Herd Size ♀♀ of all ages	Total herds No.	Total herds %	No. of Herds TT MR	TT NMR	NTT MR	NTT NMR	TT	NTT	MR	NMR
1 - 10	212	37.6	16	17	32	147	33	179	48	164
11 - 20	119	21.1	43	14	31	31	57	62	74	45
21 - 30	81	14.4	37	8	21	15	45	36	58	23
31 - 40	46	8.2	15	3	19	9	18	28	34	12
41 - 50	29	5.1	16	3	8	2	19	10	24	5
51 - 60	30	5.3	22	3	5	-	25	5	27	3
61 - 70	14	2.5	11	1	2	-	12	2	13	1
71 - 80	11	2.0	7	1	3	-	8	3	10	1
81 - 90	6	1.1	4	1	1	-	5	1	5	1
91 - 100	3	0.5	3	-	-	-	3	-	3	-
100	13	2.3	13	-	-	-	13	-	13	-
Total ..	564	100.1	187	51	122	204	238	326	309	255
Observed %			33.1	9.0	21.7	36.3	42.1	58.0	54.8	45.3
Expected %			23.1	19.1	31.7	26.1				

DEXTER (37 herds) 1939.

Herd Size ♀♀ of all ages	Total herds No.	Total herds %	No. of Herds TT MR	TT NMR	NTT MR	NTT NMR	TT	NTT	MR	NMR
1 - 10	24	64.9	-	-	1	23	-	4	1	23
11 - 20	6	16.2	-	1	1	4	1	5	1	5
21 - 30	5	13.5	1	-	3	1	1	4	4	1
31 - 40	2	5.4	1	-	1	-	1	1	2	-
41 - 50										
51 - 60										
61 - 70										
71 - 80										
81 - 90										
91 - 100										
100										
Total ..	37	100	2	1	6	28	3	34	8	29
Observed %			5.4	2.7	16.2	75.7	8.1	91.9	21.6	78.4
Expected %			1.8	6.4	19.8	72				

TT = tuberculin tested
NTT = non-tuberculin tested

MR = milk recorded
NMR = non-milk recorded

small herds in the latter. The Dexter breed, however, is seen to consist of only 37 herds (in 1939 herdbook); all of them are small, and most of them are very small.

Tuberculin Testing.

37% of all Guernsey herds were tested, 42% of all Jersey herds, and 8% of all Dexter herds. These figures would be much higher if the herds of up to 20 females were excluded for they account for 94 out of 126 non-tested Guernsey herds, and 241 out of 326 non-tested Jersey herds. There is clearly a tendency for tuberculin testing to recommend itself more to the owners of the medium and large-sized herds than to the owners of small herds. Tuberculin Testing is by no means universal in large herds, although every Jersey herd of more than 90 cows was tested.

Milk Recording.

Slightly more than half the Jersey and Guernsey herds were milk recorded (in 1940 or 1939) but only about one in five of the Dexter herds. Here again the great majority of the non-recorded herds are to be found among herds of less than 20 females of all ages.

Relation between Tuberculin Testing and Milk Recording.

This has been examined by comparing the observed percentage of herds which fall into the four categories created by the presence or absence of testing and recording with that which is expected if the practice of/

of one has no influence on the likelihood of the other being practised. Thus 37% of Guernsey herds were T.T. (tuberculin tested), and 63% N.T.T. (non-tuberculin tested); and 51.5% were M.R. (milk recorded), and 48.5% N.M.R. (non-milk recorded). If M.R. and T.T. are independent, the proportion of herds expected to be T.T. and M.R. is 37% of 51.5%, i.e., 19.1%. This process has been extended to the other categories and the comparison of expected with observed percentages is shown at the bottom of Table 1. The results for the Jersey and Guernsey herds are the same. There are 10% too many herds in the T.T.-M.R. and N.T.T.-N.M.R. categories, and 10% too few in the N.T.T.-M.R. and T.T.-N.M.R. categories. Among Dexter herds the same kind of deviations are found only not so marked. So few herds exist that the resemblance may well be accidental. The evidence from the larger breeds seems clear, that owners who practise tuberculin testing are more likely than others to practise milk recording. The association of the two is nevertheless far from complete as there are still many herds and even comparatively large herds which practise one or other but not both. About 40-45% of Guernsey and Jersey herds are neither M.R. or T.T., but the majority of these are quite small.

PART IV.

HERD DURATION AS A FACTOR IN THE BREEDING OF

PEDIGREE AYRSHIRE AND JERSEY CATTLE.

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C O N T E N T S.

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1. Introduction.

It has been shown in a preceding section that the average age of a dairy cow at calving is about 5 years. This corresponds fairly closely to the interval between generations of cows which must also be of the order of 5 years. Lush and Lacy (1932) working with cow testing data found that the average interval between dam and calf was 5.3 years, and between sire and calf, 4.2 years. Later, Lush, Holbert and Willham (1936) estimated that in pedigree Holstein-Friesian cattle in the U.S.A. the average interval was about 4.5 years. They point out that a breeder who has established his herd and become acquainted with his cattle by the time he is 30 years old, can scarcely look forward to guiding the breeding policy of that herd for more than six or seven cattle generations, and that this is rather short time in which to carry out a breeding programme. Since the evolution of a breed depends on the collective efforts of breeders, the amount of progress made must depend very much upon the duration of the herds making up the breed as well as upon the breeding skill exercised.

Very little information has been found in the literature on this subject. Donald and Auerbach (1942) studied the duration of Large White pig herds and found that a large proportion of them were of very recent origin, and that the duration of many was/

was very short. They observed that breeders themselves were subject to a severe degree of selection and that the survivors generally built up a reputation and a large output of breeding stock. As far as cattle are concerned, Donald (1944) in a preliminary study of 475 Ayrshire herds in 1939, pointed out that such a large proportion of herds were so recently started that a majority of breeders cannot have bred more than 3 generations of animals.

In view of the small amount of information, it has been thought desirable to obtain further data about the characteristics of herd duration in Britain. The work has been designed to throw light on the following aspects:

(a) the age of existing herds;
(b) the duration of herds now defunct;
(c) the relation between number of progeny registered and age of herd.

2. <u>Material and Methods.</u>

The herdbooks of the Ayrshire and Jersey breeds have been used as the sources of data. From them, the life histories of herds have been built up by recording the number of females registered each year from the first to the last entry of the various herds selected for study. The time between the first and last entries has been considered as the total duration.

Two methods of approach have been used. The first consisted in obtaining a sample of herds which were established during fixed periods of time and then/

then determining how long each herd lasted. The second consisted in working backwards from a sample of herds in existence in 1939 or 1941, to determine how long ago each of them had been founded. On analogy with the study of the ages of cows, the first method may be likened to a study of expectation of life, while the second is equivalent to a study of average age. The analogy is incomplete, for whereas it is possible to consider both average age and expectation of life in a population of cows, considerable difficulties were met in the attempt to do this with a population of herds.

Herds may last so long that the tail of a distribution of ages is lacking. If this difficulty is minimized by going back to the very earliest volumes of the herdbooks, other objections are incurred. The samples become too small, and the structure of the herdbooks makes the data difficult to collect. The exact ways in which a compromise has been effected will be described along with the data to which they refer.

Only two breeds, the Ayrshire and Jersey, have so far been studied. They must be considered separately since the nature of the data and the results of their analysis makes it undesirable to deal with both together.

To avoid confusion, a distinction has been made between the words 'entry' and 'registration'. "Entry' is/.

is used in the sense of a body of information about a particular herd, for example the herd list, or a group of pedigrees for young animals. 'Registration' is used to mean the details of pedigree, birth and so on, which accompanies the allotment of a herdbook number to a young animal. Entry is a more comprehensive term, but may on occasion be equivalent to registration.

3. The duration of Ayrshire herds started in the periods 1905-8 and 1909-12.

All herds which made their first herdbook entries of females in the years 1905-12 were divided into two four-year groups. To find these herds it was necessary to examine many previous volumes of the herdbook to make sure the herds had just been started. Incidental information about the names and ages of dams and the proportion of Appendix females was found helpful. These two groups of herds were then followed through the succeeding volumes (with notes of the number of registrations) up to 1940.

It should be pointed out that the herdbook of a particular year does not include animals born in the same year. For instance, Vol. 28, published in 1905, consisted mainly of females born between 1st July 1903 and 30th June 1904. Some females were born much earlier, one as far back as 1884, but this was exceptional. Nevertheless, it soon became apparent that herds must have been in existence in some cases long/

long before the first herdbook entries.

Conditions with regard to registration have changed somewhat since 1905. There was then one appendix. In 1908, two appendixes were instituted, A and B. From 1905-8, many herds were registered in the Breed Society which consisted in whole or part of Appendix females. This was also true from 1909-12, although to a lesser extent. Breeders joining the Society about 1905 and after could, and did, enter females of various ages, some of which were fully pedigreed, while others were in Appendix A or B. Sometimes three generations of animals, one or more in each stage of the grading up process, appeared in the same volume.

As the breed has increased in size, the numerical importance of appendix animals has decreased very considerably. In 1943 there were 14,296 fully pedigreed heifers, but only 384 Appendix A females, and 148 Appendix B females. New herds now consist but rarely of Appendix females, and therefore the first homebred entries in the herdbook indicate fairly accurately the date of starting the herd. Since it became obvious that, in 1905 and immediately after, the date of first herdbook entries was not an accurate guide to the time at which herds were established, an attempt was made to find out approximately how long herds had been in existence from/

from the dates of birth of the oldest homebred animals in the first herdbook entries. These were usually Appendix females and probably often dead at the time of registration, but they were entered for the sake of the fully graded progeny. This method must lead to an under-estimate of the ages of the herds, since the breeders concerned may have been breeding for years before joining the grading up scheme. No better method has, however, been devised for getting over the difficulty. The results are given in Table 1. It shows the minimum number of years the sample herds must have been in existence before making their first herdbook entries of either fully pedigree or appendix stock.

TABLE 1./

TABLE 1.

Minimum number of years 328 Ayrshire herds were in existence before the first herdbook entry in 1905-12.
(From year of birth of the oldest Appendix ♀♀ in first entry to year of first entry.)

Year of first H.B. entry.	Years since oldest homebred female was born.																						Total
	(P)*	P*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
1905	-	4	1	-	1	-	-	1	1	1	-	-	1	-	-	-	-	-	-	-	-	-	10 - 1 regd. on merit.
1906	-	3	3	2	-	-	-	2	2	1	1	2	-	1	-	-	-	-	-	-	-	-	17
1907	2	7	3	1	7	4	2	7	2	9	3	8	2	1	3	1	2	-	-	-	-	-	64
1908	-	11	5	2	6	5	1	2	2	6	3	3	3	3	7	1	-	-	-	2	-	-	62
Total.	2	25	12	5	14	9	3	12	7	17	7	13	6	5	10	2	2	-	-	2	-	-	154
Average	6.1 years																						
1909	1	7	1	-	-	1	-	-	-	1	2	-	-	1	-	-	1	1	-	-	-	-	16
1910	8	12	-	1	1	1	-	1	-	-	-	-	2	1	-	1	-	-	-	-	-	-	28
1911	4	9	3	3	5	7	3	2	5	7	1	-	1	3	2	-	2	1	-	2	1	1	62
1912	2	19	2	3	8	4	3	4	3	5	5	2	2	1	2	2	-	1	2	-	-	-	68
Total.	15	47	6	7	14	13	6	7	8	13	6	2	5	6	4	3	3	3	2	2	1	1	174
Average.	5.2 years																						

* ((P) Herds founded on purchased stock, partly pedigree, partly Appendix.
(P Herds founded on purchased stock, all fully pedigreed.

During the first period 1905-8, the number of herds from which first entries were made numbered 154, of which 2 started with purchased females partly pedigreed and partly appendix, and 25 with purchased females, all of which were pedigreed. These 27 herds amounted to 17.5% of the total. In the second period, 62 or 35.6% of the herds had just started with purchased stock again mainly pedigreed. The use of graded stock was already on the decline as a foundation for a herd.

The range of herd age at time of first entry was 1-20 years. The average age of the first group was 6.1 years, and of the second 5.2 years, counting the herds (P,(P)) with purchased foundation stock as one year old. The number of new herds varied greatly from year to year, the least being 10 in 1905 and the greatest being 68 in 1912. There was not a gradual increase in the number but wide fluctuations for which no explanation can be offered except possibly the degree of activity in securing new members for the Society, or economic conditions.

While working forwards to determine the further duration of the herds a further difficulty soon became apparent. While some herds were dispersed by the owner or his executors, others were taken over by a member of the original owner's family. These and other arrangements were classified as follows:

A./

A. Herds bred only by the original breeder and on the same farm.

B. Herds transferred at some time to a member of the family and kept on the same farm.

C. Herds transferred by the original breeder from Scotland to England.

D. Herds transferred by the original breeder to another farm in Scotland.

Herds which were apparently transferred to another breeder not in the family were regarded as dispersed. All the herds in the sample were established in Scotland.

Herds of the B, C, and D types introduce complications in estimating duration. Which, if any, should be added to the A type ? The transfer of ownership may well have caused a change in breeding policy (if there was one), and the shifting of a herd from one farm to another might easily lead to a rather different ideal type, or to a better or worse performance by individual animals and families. No way has been found of deciding whether or not such changes should be regarded as the end of one herd and the beginning of another, and therefore the herds have been assumed to continue their existence as long as their prefix and registered number was used. Where possible, however, the four types mentioned above have been kept separate.

Following a decision of the Breed Society, on and after July 1st, 1915, young stock were entered in a special produce register. This appeared only in the/

the herdbooks for 1917-19. All females which were entered in this register were entered again in the 1920 volume (or a later one) provided they had a calf. Herds which did not appear in the produce register or later were considered defunct. The usual herdbook entries for 1917-19 were therefore not available. Most of the animals which would have been entered were added to the 1920 numbers but losses due to sterility and other causes no doubt have reduced the total numbers to less than would have been shown if the produce register had not been introduced.

The distribution of the herds in the two samples according to total duration is given in Table 2. Total duration is counted from the year of first herdbook entry to the last. The four types of herd, A-D, have been considered separately and together, and also a few herds which were transferred by a member of the original owner's family to another part of Scotland. The data for the two samples are shown graphically in Figs. 1a and 1b.

The two samples show good agreement. Herds in the first sample have been traced up to 33-36 years, and those in the second sample up to 29-32 years. This difference arises from the fact that herds starting in 1905 could be followed for 36 years up to 1940, while those starting in 1909 could only be followed for 32 years.

TABLE 2./

TABLE 2.

Duration of Ayrshire herds making their first herdbook entries between 1905 and 1912.

A. 154 herds starting in Vols. 28-31 (1905-1908).

Type of herd Duration (years)	A		B		C		D		B and D		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
1 - 5	30	19.49	-		-		-		-		30	19.49
6 - 10	24	15.60	1	0.65	-		-		-		25	16.25
11 - 15	12	7.81	8	5.19	-		-		1	0.65	21	13.65
16 - 20	14	9.10	7	4.55	-		-		-		21	13.65
21 - 25	10	6.49	5	3.25	-		3	1.95	-		18	11.70
26 - 32	1	0.65	2	1.30	-		1	0.65	-		4	2.60
33 - 36	12	7.79	17	11.04	1	0.65	3	1.95	2	1.30	35	22.73
Total ..	103	66.93	40	25.98	1	0.65	7	4.55	3	1.95	154	100.07
											Av.	17.11

B. 174 herds starting in Vols. 32-35 (1909-1912).

Type of herd Duration (years)	A		B		C		D		B and D		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
1 - 5	49	28.16	-		-		-		-		49	28.16
6 - 10	22	12.63	3	1.72	-		1	0.58	-		26	14.93
11 - 15	17	9.76	4	2.30	-		4	2.30	-		25	14.36
16 - 20	12	6.90	5	2.87	-		2	1.15	-		19	10.92
21 - 25	5	2.87	1	0.58	-		-		-		6	3.46
26 - 28	3	1.72	1	0.58	-		-		-		4	2.31
29 - 32	13	7.47	23	13.21	1	0.58	4	2.30	4	2.30	45	25.86
Total ..	121	69.51	37	21.26	1	0.58	11	6.33	4	2.30	174	100.00
											Av.	15.06

A. Herds kept by one breeder on one farm throughout.

B. Herds transferred to another member of family but kept on same farm.

C. Herds transferred to England by original owner.

D. Herds transferred to another part of Scotland by the original breeder.

FIGURE Ia.

Duration of 154 pedigree Ayrshire herds which made their first herdbook entries in 1905-08.

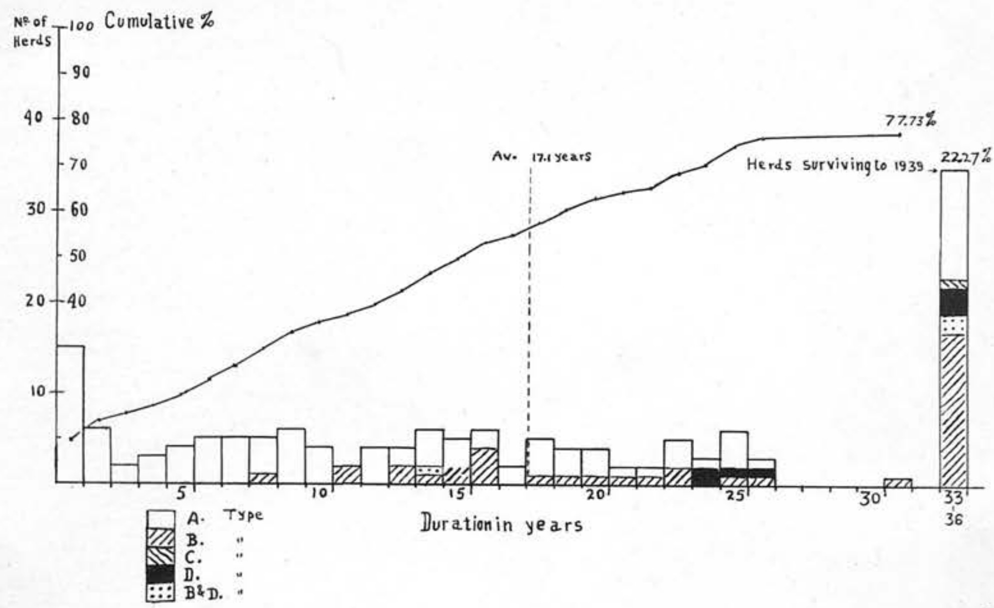
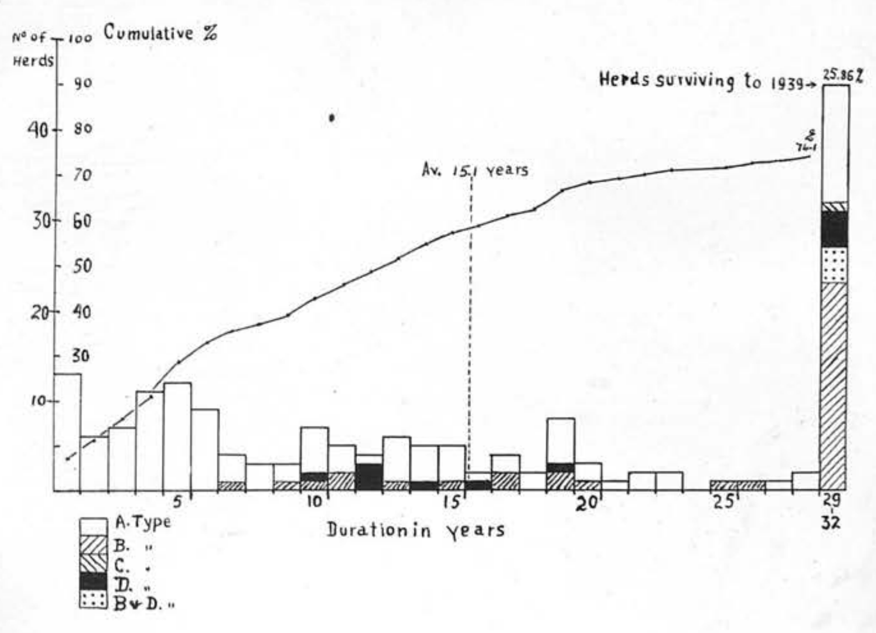


FIGURE Ib.

Duration of 174 pedigree Ayrshire herds which made their first herdbook entries in 1909-12.



Herds falling into the 33-36 year group in the first sample, and those falling into the 29-32 year group in the second sample are naturally composed of herds of two indistinguishable kinds - those which became defunct at this time and those which continued to last still longer, the total number of years under study being insufficient to allow time for all herds to become defunct. The average duration of the herds cannot therefore be accurately calculated.

Herds of the A type which remained in the owner:ship of a single breeder showed a considerable decline in number with time. Except for the oldest herds, they have been grouped into periods of 5 years to correspond roughly with the interval between generations of females. Taking the two samples together, 44 out of the original 224 herds lasted for more than 20 years, that is approximately 4 generations. B type herds, which passed to another member of the breeder's family, naturally show a much higher proportion of herds surviving beyond 20 years. Out of 77 herds of the B type, 49 lasted more than 20 years. C and D type herds, although few in number, also tended to have a comparatively long duration. About 90% of the herds founded were of either the A or the B type, and of these the latter contributed about 25-30%. Whether this proportion is character:istic of other breeds is not known, but the importance of certain families of people is a well recognised/

recognised feature of Ayrshire breeding. It is not fully brought out in these data since the maintenance of different herds by brothers and other relatives is not taken into account.

Taking all the 328 herds together, some 32% lasted for more than 20 years, and 25% for more than 25 years. Assuming that all herds still in existence in 1941 ceased then, the average duration for the first sample was 17 years, and for the second, 15 years. Since the second sample began four years later than the first, it has apparently tended to last slightly longer. If it be argued that the time spent in grading up the herds prior to the first herdbook entries should be included in the estimate of duration of pedigree herds, then as shown above 5-6 years should be added, giving a minimum estimate of 20-23 years. In some ways it seems more satisfactory to consider only the A type herds. The average duration for these, calculated in the same way, was 13.01 and 11.65 years for the first and second samples respectively, and 18.51 and 17.15 years if 5.5 years of pre-herdbook life is added. In the first group, herds which continued up till 1939 (Vol. 63, 1940) accounted for 22.73%. This percentage was made up of 10.39% belonging only to one breeder, and 12.34% belonging to more than one breeder. The corresponding values for the second period are 25.9%, 10.4%, and 15.6%, being very similar/

similar to those of the first period.

In considering these data, it has to be remembered that the breed was expanding in both the number of breeders and the number of females registered. This is brought out in Table 3, which gives the number of new herds in relation to the total number of herds registering females, and to the number of registrations.

TABLE 3./

TABLE 3.

Number of herds making herdbook entries for the first time in relation to the total herds making entries and to the total females registered.

H. B. Vol.	Year	No. of new herds registering	Total herds	Total ♀ registrations.		
				Pedigree	Appendix A	Appendix B
27	1904	-	155	951	175	
28	1905	17	137	789	150	
29	1906	17	152	912	209	
30	1907	64	231	1,639	834	
31	1908	62	274	2,012	1,350	
32	1909	16	224	1,587	35	255
33	1910	28	220	1,617	71	184
34	1911	62	309	2,443	366	902
35	1912	68	317	3,170	464	849
63	1940	98	758	11,122	195	73

The total number of herds as given in Table 3 does not include those which did not make any entries, although still in existence. Ayrshire herds have such a large average size, however, that the number missed on this account can be assumed to be very small.

In 8 years, the number of herds doubled. It was clearly a period favourable to the conduct of pedigree breeding. Since then, the breed has continued to expand up till the present time. Economic conditions would appear to have favoured the continued duration of pedigree herds and the possibility must be borne in mind that if for any reason the breed remained stationary or tended to contract in numbers, the duration of individual herds might be less than that found in the samples taken.

4. <u>The duration of breeding by individual breeders.</u>

In order to eliminate the effect of changes in herd ownership, the data have been reclassified according to the time during which the original breeder was shown in the herdbook as the breeder of the herdbook entries. The distributions for the two samples are shown in Table 4, and Figs. 2a, 2b, and 2c.

As would be expected, the distributions are similar to those for herd duration, but the average duration (calculated as before) is slightly less, at about 13 years. Allowing for the grading-up period, the/

the total duration becomes about 18-19 years. This means that the average breeder is at work for about 4 generations of cows. As shown by the last column in Table 4, however, about 64% of breeders do not continue beyond the third generation of fully pedigree stock, since they cease breeding at some time during the first 15 years.

From the genetical point of view, three generations is not very long in which to appraise the purchased foundation stock, and to carry out a breeding policy. If the first sires used were proved to be unsuccessful, very little time is left for recovery and improvement beyond the level of the original stock.

TABLE 4.

Distribution of 328 individual breeders of pedigree Ayrshire herds according to duration.

Duration (years)	First H.B. Entries 1905-08 No.	%	1909-12 No.	%	Total. No.	%	Cum. %
1 - 5	39	25.32	53	30.46	92	28.05	28.05
6 - 10	31	20.13	32	18.39	63	19.21	47.26
11 - 15	23	14.94	31	17.82	54	16.46	63.72
16 - 20	18	11.70	20	11.49	38	11.59	75.31
21 - 25	20	12.98	13	7.47	33	10.06	85.37
26 - 30	6	3.89	7	4.03	26	7.93	93.30
*31 - 35	17	11.04	*18	10.34	22	6.71	100.01
Total ..	154	100.00	174	100.00	328	100.01	
Av. (Yrs.)	14.05		12.73		13.35		

* Number registering females in Vol.63, 1940.

FIGURE 2a.

Duration of breeding by 154 individual breeders who made their first Ayrshire herdbook entries in 1905-08.

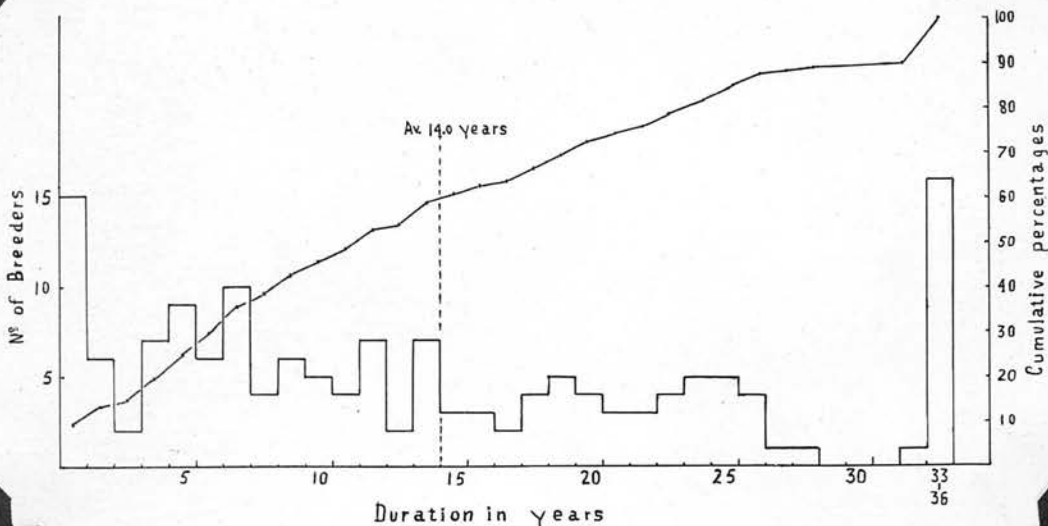


FIGURE 2b.

Duration of breeding by 174 individual breeders who made their first Ayrshire herdbook entries in 1909-12.

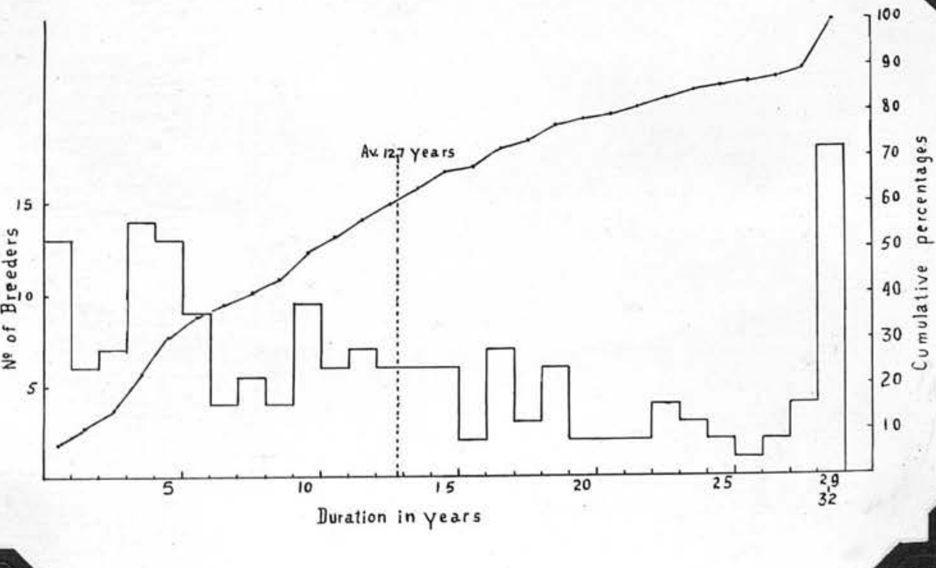
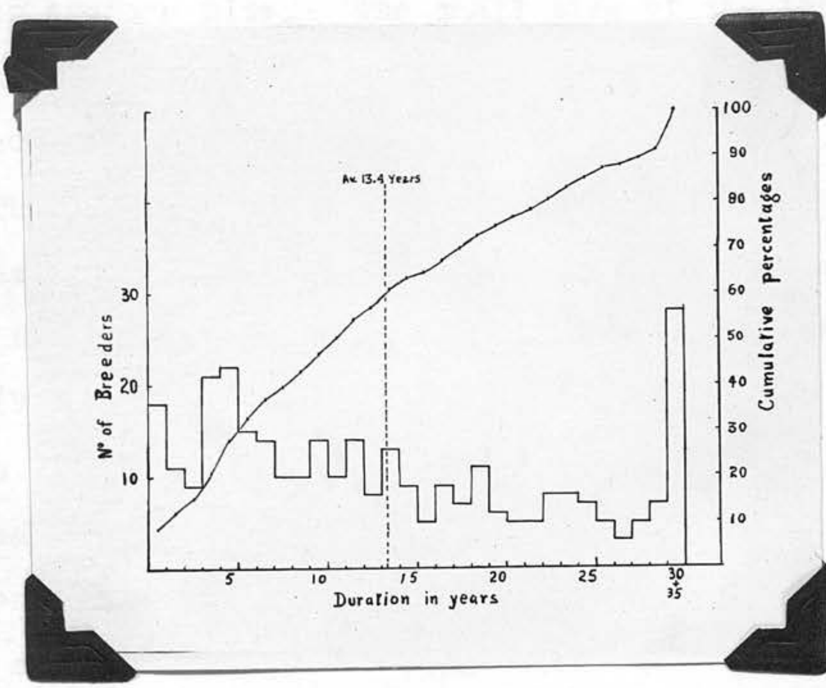


FIGURE 2c.

Duration of breeding by 328 individual breeders who made their first Ayrshire herdbook entries in 1905-12.



5. The duration of pedigree Jersey herds established since 1924.

In order to obtain an estimate of duration in a dairy breed kept under different conditions from those characteristic of Ayrshire cattle, a sample of herds has been taken for the Jersey breed. The majority of Jersey herds are located further south than the majority of Ayrshire herds, and they tend to be of smaller average size. The small size of the Jersey cow and her high butterfat percentage may be assumed to recommend her to a different class of breeder.

The method of obtaining the sample of herds was somewhat different from that used for Ayrshire herds owing to the nature of the Jersey herdbook. Until 1930 (Vol. 42), the herdbook contained a list of births for the year, together with the pedigrees of such males and females born the previous year as the breeders wished to register. The list of births was given alphabetically according to the owner's name, and the appearance of new herds or the discontinuance of old ones could be determined from it. Information about the number of births was useful for comparison with the number of animals registered with pedigrees in the next or later volumes of the herdbook. From 1931 onwards, the list of births was deleted, and in its place the herdbook contained a list of all registered animals of all ages in each herd up to 31st December. The pedigree entries were continued as/

as before, the year of the herdbook being the same as that in which the females were born. The herd lists were tabulated alphabetically according to the owner's surname, and the animals were grouped under the headings "Bulls", "Heifers and Cows in milk", and "Heifers and Young Female Stock". Their dates of birth and herdbook numbers were also stated. Stock imported from Jersey was designated as such.

The sample was obtained by selecting all new herds, the owners of which had surnames beginning with the letters B, D, F, H, L, N, P, S, W. To guard against the possibility that herds not mentioned in the list of births or in the herd lists might nevertheless continue registrations, the latter were examined during the collection of data on the duration of the herds. As before duration is assumed to be the time between first and last appearance of the herds in the birth lists, herd lists, or pedigree entries.

During the 18 years from 1924 to 1941, 665 new herds were established by owners with the selected initials. These were sub-divided into groups beginning in each of 6 three-year periods, and the number of herds becoming defunct year by year up to 1941 noted. Table 5 presents the results. Fig. 3 shows the distribution of durations for herds starting in the shorter period 1924-29.

TABLE 5./

TABLE 5.

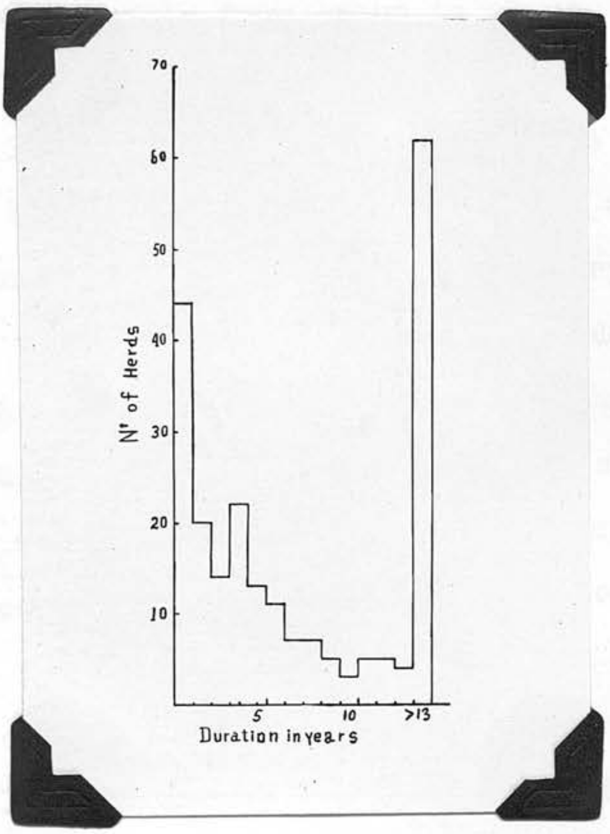
Distribution of 665 pedigree Jersey herds started since 1924 according to duration (up to 1941).

Herds starting	Vols. 36-38 1924 - 1926		Vols. 39-41 1927 - 1929		Vols. 42-44 1930 - 1932		Vols. 45-47 1933 - 1935		Vols. 48-50 1936 - 1938		Vols. 51-53 1939 - 1941		Total	Defunct herds. as % of total (weighted av.)	Defunct herds. as % of survivors
Duration (yrs)	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%			
1	30	22.7	14	15.6	15	18.1	16	11.6	19	18.1	6	5.1	100	17.2	17.2
2	9	6.8	11	12.2	8	10.8	17	12.3	10	9.5	4	3.4	59	10.0	12.1
3	9	6.8	5	5.6	6	7.2	12	8.7	14	13.3			46	8.4	11.0
4	10	7.6	12	13.3	6	7.2	10	7.2	5	4.8			43	8.6	13.4
5	9	6.8	4	4.4	4	4.8	12	8.7	5	4.8			34	6.5	11.6
6	5	3.8	6	6.7	6	7.2	6	4.3					23	5.2	10.3
7	5	3.8	2	2.2	3	3.6	5	3.6					15	3.3	7.0
8	3	2.3	4	4.4	6	7.2	1	0.7					14	4.3	10.0
9	3	2.3	2	2.2	3	3.6							8	2.6	6.4
10	3	2.3	-	-	4	4.8							7	1.4	3.6
11	3	2.3	2	2.2	2	2.4							7	2.3	6.3
12	2	1.5	3	3.3									5	2.3	6.7
13	3	2.3	1	1.1									4	2.3	7.2
14	1	0.8	1	1.1									2	0.8	
15	5	3.8											5	3.8	
16	-	-											-	-	
17	6	4.5											6	-	
Total (defunct)	106	80.3	67	74.4	63	75.9	79	57.1	53	50.5	10	8.5	378	79.0	
in existence (1941)	26	19.7	23	25.6	20	24.1	59	42.9	52	49.5	107	91.5	287 *	21.0	

* These herds were started in 1924 or later. 58 others still in existence in 1941 were started before 1924.

FIGURE 3.

Distribution according to duration of 222 pedigree Jersey herds started in 1924-1929.



The tails of each distribution are too small as a result of the grouping. The last two values are necessarily based on smaller numbers than the earlier values, as for instance, herds starting in 1924 can be followed for 17 years, while those starting in the same group but two years later can only be followed for 15 years. Allowing for this, it will be seen that the proportion of herds becoming defunct at each age varies considerably from group to group. Herds lasting only one year for instance were 22.7% of the total in the 1924-26 group, and 11.6% in the 1933-35 group. The numbers of herds in each group are too small, however, to make such comparisons very useful. A method has therefore had to be found for developing an average for all groups combined. This has been done by (a) disregarding the last two values in the tail of each distribution; (b) taking the appropriate weighted percentage for each year of duration. Thus of 100 herds found to be defunct at the end of the first year (column headed 'total') six come into the tail of the last group and are deducted. The 94 remaining arose from 665 herds less those which were first found in the last group, that is from 665-117 or 548 herds. The percentage of losses in the first year is thus 17.2%. The second year was likewise based on 55 out of 548 herds giving 10.0%. Proceeding to the fifteenth year in this way a weighted average is/

is obtained based on the available data. It would not be expected that the percentages so estimated would add up to 100%. Apart from the varying number of herds used, there is a proportion of herds which would survive beyond 15 years. There were 24.2% of these in the first group. If this were typical, herds dispersed before 15 years should amount to about 76%. The sum of the estimated percentage losses at each age comes to 79% which may be regarded as reasonably close under the circumstances.

The percentage of losses appears to decline up to about the tenth year, but this does not necessarily mean that the 'mortality' among the survivors declines. The percentage of herds disappearing at each age has therefore been expressed as a percentage of the survivors up to that age as a measure of the 'mortality'. The values for this are given in the last column. Up to about the thirteenth year, it appears that the chances of a herd surviving from one year to the next do improve. Whereas as 17% of herds disappeared after one year, only about 7% of those reaching 13 years failed to continue. The figures beyond this point are too small to be of much value.

It can also be seen from Table 5 that about 50% of the herds established disappear during the first five years, while another 17% disappear during the next five years. These losses are much larger than those found for Ayrshire herds in Table 2 (p.121), namely/

namely 19% and 28% (for the two samples) in the first 5 years, and 16% and 15% in the next 5 years. The Jersey and Ayrshire samples are not perfectly comparable because (a) the basic years for sampling are different; and (b) no prior grading up period has occurred with Jersey herds and perhaps therefore no time has been allowed for the less enthusiastic and persistent breeders to be culled from the sample. It would not be surprising, however, if Jersey herds did have a somewhat shorter existence owing to their smaller average size and to the frequency with which they appear to be merely adjuncts to herds of other breeds.

All the herds in the Jersey sample were continuously in the hands of their original breeders. This is a rather interesting difference from the Ayrshire samples in which a considerable number of transfers were found. There has not been as long, of course, for the transfers to take place, since the Ayrshire sample dates from 1905 and the Jersey only from 1924.

6. <u>The distribution of Ayrshire herds in 1939 according to duration, and the influence of duration on numbers of herdbook registrations.</u>

It is of interest to know how long the herds of today have been in existence, as well as how long they may be expected to last. The age distribution of/

of existing herds will show how the experience of breeders, and the time during which they have been able to modify their cattle, varies from herd to herd. It may be expected to fluctuate considerably with economic conditions since a large influx of new breeders will obviously reduce the average age, while periods of economic depression will reduce the numbers of recruits relative to the number of established breeders, thereby tending to raise the average age of herds.

All Ayrshire herds which registered females in the 1940 herdbook have therefore been traced backwards to find the year when they made their first herdbook entries. As before, the duration of these herds has been taken as the difference between the two dates. Some existing herds will not have made any herdbook entries but these can be assumed to be few when herd size is large as in the Ayrshire breed. In addition to these, there were 15 herds (out of 773 making entries) which registered males only. The herds were then classified according to duration with the results given in Table 6 and Fig. 4. This table also shows details of the number of herdbook registrations of these herds in the 1940 herdbook.

TABLE 6./

TABLE 6.

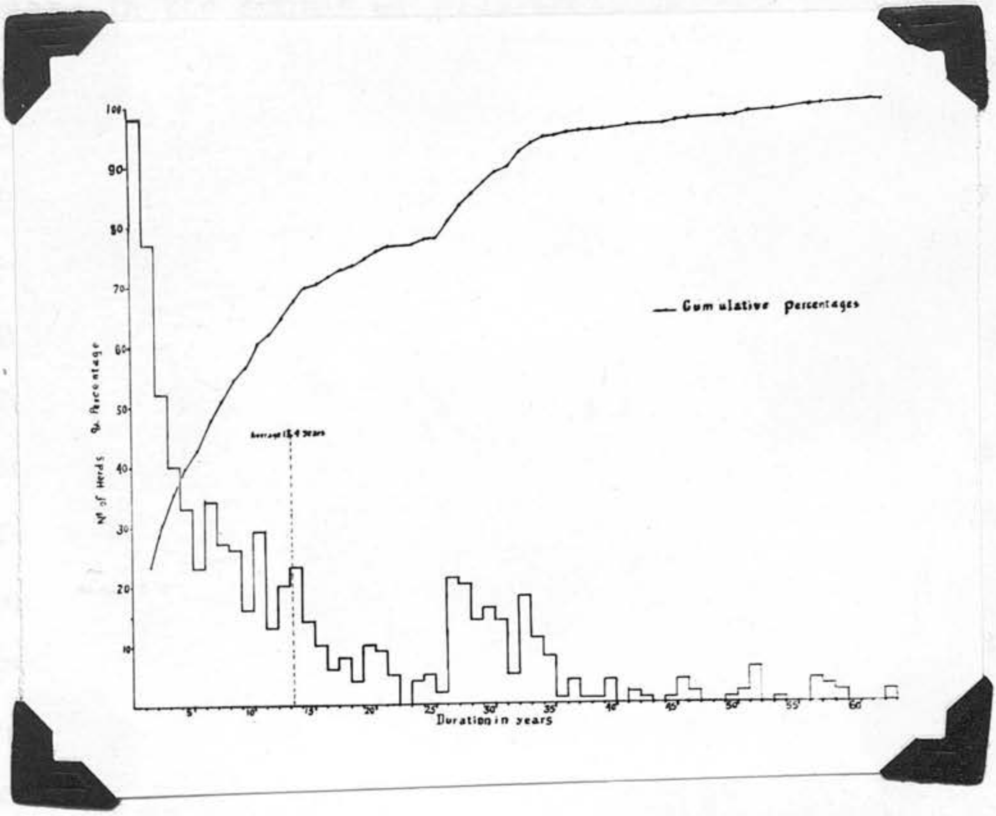
Age distribution of 758 pedigree Ayrshire herds making herdbook entries in 1939, and number of ♀♀ and ♂♂ registered by them in Vol. 63 (1940).

Duration (years)	Herds.			♀♀ registered.		Average per entry	♀♀ registered				♂♂:♀♀ registered.
	No.	%	Cumulative %	No.	%		No.	%	Herds making the entries. No.	Herds making the entries. %	
1 - 5	301	39.7	39.7	2,792	24.6	9	372	18.9	160	53.4	1 : 7.5
6 - 10	126	16.6	56.3	1,820	16.0	14	332	16.9	81	64.3	1 : 5.5
11 - 15	99	13.1	69.4	2,019	17.8	20	269	13.7	60	60.6	1 : 7.5
16 - 20	38	5.0	74.4	709	6.2	19	160	8.1	30	79.0	1 : 4.4
21 - 25	23	3.0	77.4	540	4.7	23	103	5.2	17	72.6	1 : 5.2
26 - 30	73	9.6	87.1	1,376	12.1	19	234	11.9	54	74.0	1 : 5.9
31 - 35	56	7.4	94.5	1,128	9.9	20	203	10.3	40	71.4	1 : 5.6
36 - 63	42	5.5	99.9	985	8.7	23	293	14.9	35	83.3	1 : 3.4
Total or Average	758	99.9		11,369	100.0	15	1,966	99.9	477	62.9	1 : 5.8

Average Duration : 13.4 years

FIGURE 4.

Distribution of 758 pedigree Ayrshire herds existing in 1939 according to duration.



Most of the females registered in the 1940 herd:
:book were born between July 1938 and June 1939 and most of the entries probably were made during 1939 which was a year of expansion in the breed. Some 12% more heifers were entered than in the previous year, so that conditions may be assumed to have been favourable to the establishment of new herds. These conditions, to judge by the steady increase in recent years in the number of registrations, are not peculiar to 1939. The observed proportion of herds which had been making entries for only 1-5 years (39.7%) is therefore likely to be typical for the period. The cumulative percentages shown in the 4th column of Table 6 show that 74.4% of all 758 herds had lasted for 20 or fewer years. This proportion is similar to the 68% found for herds beginning in 1905-12; in fact the distributions of durations for existing herds and for those starting between 1905 and 1912 may be regarded as much the same, especially in view of the effects the varying influx of new breeders might be expected to have.

The average duration of all herds existing in 1939 was found to be 13.4 years, regardless of changes in ownership. The oldest herd was 63 years. Comparison with Table 2 (p. 121) will show that the average duration of existing herds in 1939 was 2-4 years less than the duration of herds starting in 1905-12. The latter, however, underestimates duration/

duration since it has not been possible to follow all herds to their ultimate dispersal. The actual duration will probably vary from time to time according to economic factors.

The numbers of females registered by herds of varying age, the relation of these numbers to the total female registrations, and the average number of females entered per herd in the 1940 volume of the herdbook, are shown in the next section of Table 6. Total female registrations numbered 11,390, of which 21 are not accounted for, unless they are due to the omission of certain numbers unsuitable for tattooing. It will be seen that there is a close correspondence between the percentage of all herds with a given duration and the percentage of all female registrations coming from those herds. This is because the number of registrations per herd (which is a fairly accurate measure of herd size) is fairly uniform as between herds of different durations, except that the youngest herds make fewer registrations and contribute only 24.6% to total registrations instead of 39.7% as would be expected from their frequency. It would appear that in recent years new Ayrshire herds start with wholly or mainly pedigree animals, and at a size which is about half of that which they attain during the next ten years.

The last section of Table 6 deals with the number of bull registrations. Here, the youngest herds are seen/

seen to have registered relatively many fewer bulls than herds of over 15 years' duration. Herds of intermediate duration (6-15 years) registered bulls in proportion to their numbers, but each age class thereafter exceeded the expected numbers. The 39.7% of herds of 1-5 years' duration contribute only 18.9% of the bulls, while the 8.4% of herds over 36 years old contribute 17.8%. The reason for this appears to be that whereas about half of the youngest herds registered no bulls, most of the oldest herds registered one or more. The ratio of male to female registrations which is shown in the last column varies from 3.4 females per male from the oldest herds to 7.5 females per male from the youngest herds. While this difference is not unexpected, there is much variation in the ratio from one age class of herds to another. If it is due to chance, the observations for the oldest and youngest herds may not have much significance. The general impression is that herds of 1-5 years' duration are smaller than older herds and register a smaller proportion of their bull calves, but that they quickly attain maturity in this respect. Bull breeding which is the most responsible task of pedigree breeders is by no means left to herds of long standing. Nearly 36% of bulls registered in the 1940 herdbook were from breeders with ten or fewer years of experience in pedigree breeding.

The relation between duration and total contribution/

contribution of pedigree animals to the breed has been investigated in the 328 herds which started in 1905-12. Details are shown in Table 7. The first point which may be noticed is that while herds of 1-5 years' duration amounted to about 40% of all herds existing in 1939 (Table 6, p.139), the proportion of herds which actually ceased to exist in the first five years of their life was about 25%. The latter figure of course applies to a much earlier period, but the difference would not be unexpected since in a growing breed average age of herd will be less than average duration. There is a corresponding excess of old herds when total duration is compared with the partial duration of existing herds.

The average number of females registered per year by herds starting in 1905-12 showed a marked tendency to rise with the passage of time. The herds which became defunct during their first five years registered only 3.4 females per year while those which survived longest averaged (in the second sample) 16.1 per year. This suggests that their herd size was about 80 females of all ages. Whether the short-lived herds failed to survive because of their small size, or whether the herds with long durations started with equally small herds, has not yet been determined. The tendency to expand with age is also shown by the figures given for the number of registrations made in the last five herdbook entries by/

by each herd. These are in general slightly larger than the average number of registrations for all years, and suggest that the oldest herds started smaller than they are now but not as small as the herds which ceased while still young.

Old herds have naturally contributed far more animals to the breed than young herds. The extent of the difference is shown in the next columns of Table 7. In the first sample, for instance, the 30 herds defunct within the first five years registered altogether 223 females, while the 35 herds which started at the same time but lived for 33 or more years had accumulated the incomplete total of 15,085. The last column shows the proportion of Appendix females in the entries. About half the entries from short-lived herds consisted of Appendix females, but as duration increased the proportion decreased at approximately the same rate in both samples. There is a difference between the ratios for the oldest herds in each group, but the age difference probably accounts for this.

TABLE 7./

TABLE 7.

Relation between the duration of 328 pedigree Ayrshire herds and number of herdbook registrations.

A. Herds starting in Vols. 28-31 (1905-1908).

Duration (years)	Herds		Entries		Av. No. ♀♀ registered per herd per year.	(See X below.)	Total No. of ♀♀ registered.			Ratio App. Ped. ♀♀
	No.	%	Total	%			Ped.	App.	Total	
1 - 5	30	19.49	56	2.84	3.4	-	119	104	223	1 : 1.14
6 - 10	25	16.25	133	6.75	6.8	-	961	394	1,355	1 : 2.4
11 - 15	21	13.65	182	9.24	9.4	9.8	1,859	789	2,648	1 : 2.4
16 - 20	21	13.65	244	12.39	8;9	7.8	2,775	587	3,362	1 : 4.7
21 - 25	18	11.70	304	15.44	10.8	11.0	3,929	644	4,573	1 : 6.1
26 - 32	4	2.60	91	4.62	12.0	11.8	1,205	102	1,307	1 : 11.8
* 33 - 36	35	22.73	959	48.70	14.5	17.2	13,915	1,170	15,085	1 : 11.9
Total	154	100.07	1,969	99.98			24,763	3,790	28,553	

B. Herds starting in Vols. 32-35 (1909-1912).

Duration (years)	Herds		Entries		Av. No. ♀♀ registered per herd per year.	(See X below.)	Total No. of ♀♀ registered.			Ratio App. Ped. ♀♀
	No.	%	Total	%			Ped.	App.	Total	
1 - 5	49	28.16	127	6.18	7.2	-	472	610	1,082	1 : 0.8
6 - 10	26	14.93	142	6.91	8.8	-	974	803	1,777	1 : 1.2
11 - 15	25	14.36	225	10.94	10.0	8.7	2,296	958	3,254	1 : 2.4
16 - 20	19	10.92	250	12.16	13.9	11.3	3,768	819	4,587	1 : 4.6
21 - 25	6	3.46	115	5.59	11.9	13.2	1,389	233	1,622	1 : 6.0
26 - 28	4	2.31	83	4.04	12.9	14.2	1,154	256	1,410	1 : 4.5
* 29 - 32	45	25.86	1,114	54.19	16.1	20.2	19,020	2,734	21,754	1 : 7.0
Total	174	100.00	2,056	100.01			29,073	6,413	35,486	

X .. Average Number of ♀♀ registered in last 5 entries.

* .. These herds were still in existence in 1939.

7. <u>The distribution of Jersey herds in 1941 according to duration, and the influence of duration on number of herdbook registrations.</u>

Before considering the duration of herds as they were in 1941, it may be helpful to consider the rate at which new herds appeared during the preceding years. The necessary data are given in Table 8 and Fig. 5. These show the total number of herds in the herd lists from 1923 to 1941, together with the numbers of herds which arose or disappeared year by year. The data do not cover the whole breed, but include all herds whose owners, as explained above, had names beginning with the initials B, D, F, H, L, N, P, S, W. The average number of herds during these 18 years was 333, the smallest number (288) being found in 1931, and the largest (372) in 1936. The number of new herds varied from 19 to 59 per year with an average of 36.9. This number expressed as a percentage of all herds varied from 18.04% to 6.13% with an average of 11.07%. Almost balancing the new herds were the losses due to dispersal or cessation of pedigree breeding. Herds becoming defunct (for pedigree purposes) ranged in number from 17 in 1932 to 53 in 1931, the yearly average being 34.8, thus leaving a net gain in number of practically 2 herds per year. The number of defunct herds expressed as a percentage of the total herds of the previous year varied about a mean of 10.5% with a maximum of 17.1% in 1931 and a minimum of 5.9% in 1932. While the starting of new herds may well/

well be influenced by the activity of the Breed Society, the impact of economic conditions can be seen in excess of losses over gains during 1928-31 and 1937-40, and in the excess of gains over losses in 1932-36.

Young males and females registered from these herds also varied considerably from year to year, but taking all 18 years together, 333 herds registered 177 bulls and 1360 heifers. This is roughly half a bull and four heifers per herd per year, and a ratio of 8 heifers to one bull. For the whole breed in 1941, there were 402 bull and 3119 heifer registrations, and in 1940, 372 and 3435. Comparison of these figures with those in Table 8 indicates that the sample refers to about half the herds, for the registrations of heifers from them amounted to about half the breed total. The sample, however, appears to have been somewhat atypical in bull breeding since thennumber of bulls registered was noticeably less than half the breed total.

TABLE 8./

TABLE 8.

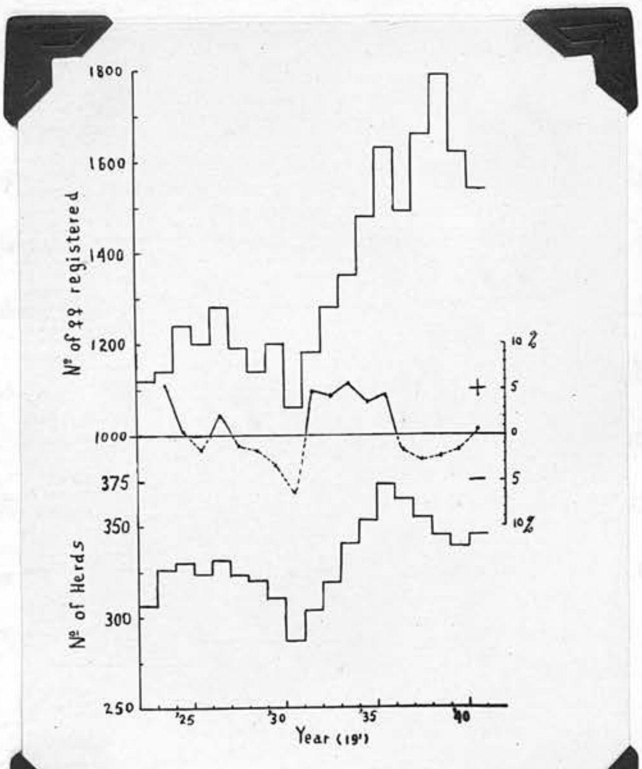
Number of pedigree Jersey herds, new herds, and registrations from 1923-41. Sampling according to initial of owners' surnames.

Vol.	Year	No. of Herds.	No. of New Herds.	New herds as % of current year.	No. of defunct herds	Defunct herds as % of previous year	No. of young registered. ♂♂	No. of young registered. ♀♀
35	1923	306					169	1,113
36	1924	327	59	18.04	38	12.42	212	1,143
37	1925	330	46	13.94	43	13.15	202	1,240
38	1926	323	27	8.36	34	10.33	196	1,204
39	1927	331	34	10.27	26	8.05	193	1,277
40	1928	327	28	8.56	32	9.67	222	1,190
41	1929	321	28	8.72	34	10.40	205	1,141
42	1930	310	19	6.13	30	9.35	239	1,204
43	1931	288	31	10.76	53	17.10	122	1,058
44	1932	304	33	10.85	17	5.90	118	1,184
45	1933	319	47	14.73	32	10.53	143	1,277
46	1934	340	45	13.24	24	7.52	162	1,346
47	1935	354	46	12.99	32	9.41	204	1,480
48	1936	372	47	12.63	29	8.19	178	1,628
49	1937	366	33	9.02	39	10.48	160	1,489
50	1938	355	25	7.04	36	9.84	203	1,660
51	1939	346	40	11.56	49	13.80	137	1,785
52	1940	339	26	7.67	33	9.54	140	1,622
53	1941	345	51	14.78	45	13.27	154	1,544
Total ..		5,997	665	199.29	626	188.95	3,190	24,472
Average (18 years)		333	36.9	11.07	34.8	10.50	177	1,360

N.B. Bulls and heifers born in 1924-1930 were registered in the following year, while those born in 1931 onwards are born and registered in the same year.

FIGURE 5.

No. of herds and registrations in a sample of the Jersey breed, together with the difference in the percentage of new and defunct herds.



Turning now to the 345 herds which were in existence in 1941, attention may be directed to Table 9 and Fig. 6, in which they are classified according to their duration.

The number and percentage of herds of each duration show how the more youthful herds predominate, and how they diminish with the passage of time. The number of females and males which they have registered, shown in the next columns, gives the total contributions of each class of herd to the breed. The longest established herds naturally have contributed far more than the rest, but the small numbers of herds in most of the classes, combined with the variation which no doubt exists among them in size, makes it difficult to draw any conclusions on this data about the relation between age and total contribution. It seems clear, however, that as herds mature they grow in size since, for example, herds of 9 years' duration, which averaged a total of 46 female registrations, contributed more than three times the number of animals than herds of three years' duration, which averaged a total of 9.4 animals. The same remarks apply to the number of males registered.

The next column headed number of entries, gives the number of occasions on which the herds in each class registered one or more animals in the herdbooks. Thus, of the 51 herds in the herd list for 1941 which had been in existence for only one year, only 17 made registrations of males or females. Herds of two

years'/

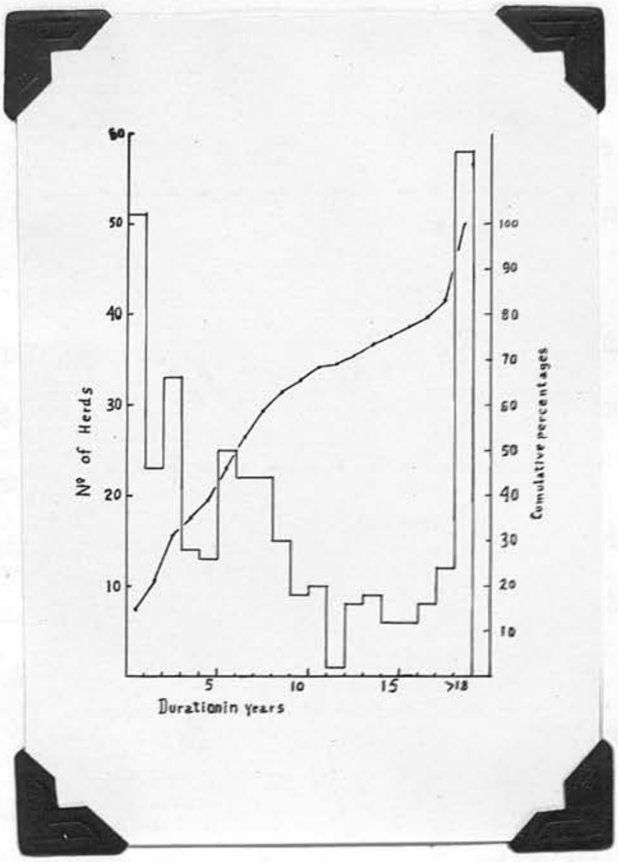
TABLE 9.

Distribution of 345 Jersey herds in existence in 1941 according to duration.

Duration (years)	Herds		Registered ♀♀		Registered ♂♂		No. of Entries		Average No. of ♀♀	
	No.	%	No.	Per herd	No.	Per herd	No.	Per herd	Per Year	Per entry
1	51	14.8	53	1.0	6	0.1	17	0.3	1.0	3.1
2	23	6.7	82	3.6	7	0.3	40	1.7	1.8	2.0
3	33	9.6	310	9.4	26	0.8	64	1.9	3.1	4.8
4	14	4.1	250	17.9	18	1.3	46	3.3	4.5	5.4
5	13	3.8	498	38.3	29	2.2	55	4.4	7.6	9.1
6	25	7.2	406	16.2	41	1.6	122	4.9	2.7	3.3
7	22	6.4	614	27.9	54	2.5	115	5.2	4.0	5.3
8	22	6.4	711	32.3	47	2.1	141	6.4	4.0	5.0
9	15	4.3	695	46.3	118	7.9	106	7.1	5.1	5.9
10	9	2.5	460	51.1	101	11.2	78	8.7	5.1	4.5
11	10	2.9	310	31.0	16	1.6	75	7.5	2.8	4.1
12	1	0.3	96	96.0	-	-	9	9.0	8.0	10.6
13	8	2.3	647	80.9	74	9.3	100	12.3	6.2	6.5
14	9	2.6	385	42.8	82	9.1	108	12.0	3.0	3.6
15	6	1.7	992	165.3	118	19.7	83	13.8	11.0	12.0
16	6	1.7	356	59.3	34	5.7	93	15.5	3.7	3.9
17	8	2.3	467	58.4	36	4.5	122	15.3	3.4	3.8
18	12	3.5	1,573	131.1	149	12.4	177	14.8	7.5	8.9
> 18	58	16.8	7,265	125.2	957	16.5	1,047	18.1	6.6	6.9
Total or Average.	345		1,670	46.9	1,913	5.5	2,598		5.4	6.2

FIGURE 6.

Distribution of 345 pedigree Jersey herds existing in 1941 according to duration.



years' duration, numbering 23, could have had a maximum of 46 entries of one or more animals if each herd had made an entry in each year, but actually only 40 entries were made. Some herds must therefore have missed making entries in one or both years. Likewise herds of 10 years' duration made 78 entries where 90 were possible. As herds become larger and better established, failure to make any entries becomes less frequent. The newly established herds, however, are often not represented in the registrations (as compared with the herd lists) and this needs to be borne in mind in making deductions regarding the number and size of herds from details of registrations in a single herdbook.

The average number of females registered per year of duration which is shown in the last column also brings out the small size of youthful herds. After they have lasted for about 4 years, the average number of registrations fluctuates considerably, but in general herd size would not appear to change much after this. The fluctuations could be explained by the chance distribution of large and small herds in the comparatively small samples available for each age class.

In order to overcome this difficulty of small numbers Table 10 has been constructed from Table 9 to give a more generalized picture. The preponderance of young herds is clearly seen. About 76% of all herds/

herds were of 1-15 years' duration, and about 39% of 1-5 years' duration. After 5 years, the rate of registering males and females rose noticeably, and also the ratio of females per male registration. By this time, perhaps, those breeders whose facilities, skill, or interest, had proved unequal to the task of pedigree breeding had been eliminated.

If Table 10 is compared with Table 6 for the Ayrshire herds (p.139), it will be found that the two distributions of herd duration are not unlike. New herds of 1-5 years' duration amounted to 38.8% and 39.7% of the totals for Jersey and Ayrshire herds. Herds over 15 years old amounted to 24.3% and 30.6%. The number of registrations differed considerably, being 6 per entry for Jerseys and 15 for Ayrshires, indicating average herd sizes of the order of 30 and 75. The oldest herds were only slightly larger at 35 total females for Jerseys, but much larger, at about 100 females, for Ayrshires. Ayrshire breeders raised relatively more bulls than Jersey breeders, the ratio of males : females being 1 : 5.8 for Ayrshires and 1 : 8.5 for Jerseys. In both breeds many of the most experienced breeders (in terms of herd duration) registered no bulls at all.

TABLE 10./

TABLE 10.

Distribution of 345 pedigree Jersey herds in 1941 according to duration, and the relation between duration and herdbook registrations.

Duration (years)	Herds			♀♀ registered		Av. No. of ♀♀ registered per		♂♂ registered		♂♂:♀♀
	No.	%	Cumulative %	No.	Per herd.	Year	Entry	No.	Per Herd	
1 - 5	134	38.8	38.8	1,193	8.9	3.8	5.4	86	0.6	1 : 14
6 - 10	93	27.0	65.8	2,886	31.0	4.1	5.1	361	3.9	1 : 8
11 - 15	34	9.9	75.7	2,430	71.5	5.5	6.5	290	8.5	1 : 8
16 - 18	26	7.5	83.2	2,396	92.2	5.4	6.1	219	8.4	1 : 11
>18	58	16.8	100.0	7,265	125.3	6.6	6.9	957	16.5	1 : 8
Total or Average.	345	100.0		16,170	46.9	5.4	6.2	1,913	5.5	1 :8.5

The question whether herds in existence differ in any way from herds which have ceased pedigree breeding probably depends on the characteristics involved. Since there is a higher 'mortality' among young herds, the losses of herds accumulated over a period of time would be expected to show an excess of young herds compared with the age distribution of herds in existence at any particular time. This difference may, in fact, be observed by comparing Table 10 with Tables 11 and 12, which give a detailed and a condensed account of all the herds, the total duration of which fell within the period 1924-41. The distribution of durations in these two tables gives neither the distribution of herds starting within a particular time, or in existence at a particular time. The tables serve merely to compare the herdbook registrations of herds of various durations.

As in the Ayrshire breed, herd size increases with duration, and consequently Tables 11 and 12 show comparatively small numbers of females registered per herd per year because of the excess of small herds. It will be noted that the ratio of males to females does not alter much with duration and so is unaffected in Table 12, although it is surprising that the ratio should be as high as 1:7 in the herds which ceased during their first five years.

TABLE 11./

TABLE 11.

Duration and number of registrations of 378 pedigree Jersey herds started and dispersed within the period 1924-41.

Duration (years)	Herds		♀♀ registered		♂♂ registered		No. of entries		Av. no. of ♀♀ reg. per herd per	
	No.	%	No.	%	No.	%	No.	%	year	entry
1	100	26.5	137	3.6	25	5.2	84	6.5	1.4	1.6
2	59	15.6	163	4.3	30	6.3	86	6.7	1.3	1.9
3	46	12.2	315	8.3	45	9.4	109	8.5	2.3	2.9
4	43	11.4	351	9.2	37	7.7	146	11.3	2.0	2.4
5	34	9.0	406	10.7	48	10.0	135	10.4	2.4	3.0
6	23	6.1	398	10.4	40	8.4	109	8.5	2.9	3.7
7	15	4.0	325	8.5	35	7.3	83	6.4	3.1	3.9
8	14	3.7	352	9.2	35	7.3	89	6.9	3.1	4.0
9	8	2.1	141	3.7	27	4.6	61	4.7	2.0	2.3
10	7	1.9	168	4.4	29	6.1	53	4.1	2.4	3.2
11	7	1.9	231	6.1	11	2.3	68	5.3	3.0	3.4
12	5	1.3	70	1.8	36	7.5	57	4.4	1.2	1.2
13	4	1.1	135	3.5	23	4.8	44	3.4	2.6	3.1
14	2	0.5	73	1.9	10	2.1	28	2.2	2.6	2.6
15	5	1.3	220	5.8	29	6.1	63	4.9	2.9	3.5
16	-	-	-	-	-	-	-	-		
17	6	1.6	326	8.6	23	4.8	74	5.7	3.2	4.4
Total or Average.	378	100.2	3,811	100.0	478	99.9	1,289	99.9	2.4	3.0

TABLE 12.

Duration and number of registrations of 378 pedigree Jersey herds started and dispersed within the period 1924-41.

Duration (years)	Herds		♀♀ registered		♂♂ registered		♂♂:♀♀	Entries of reg. ♀♀		Av. No. of ♀♀ reg. per herd per	
	No.	%	No.	Per herd	No.	Per herd		No.	%	Year	Entry
1 - 5	282	74.7	1,372	4.9	185	0.7	1 : 7	560	43.4	1.96	2.4
6 - 10	67	17.8	1,384	20.7	161	2.4	1 : 9	395	30.6	2.78	3.5
11 - 17	29	7.7	1,055	36.4	132	4.6	1 : 8	334	25.9	2.67	3.2
Total.	378	100.2	3,811		478			1,289	99.9		
Average.				10.1		1.3	1 : 8			2.40	3.0

8. The history of individual herds.

In their study of Large White pig herds, Donald and Auerbach (1942) found that long duration was usually associated with a marked tendency to increase in herd size, as has also been found in Ayrshire and Jersey herds. The possibilities of expansion with pigs are, of course, greater than with cattle from which all female progeny are generally registered and which are frequently more directly related to the carrying capacity of the farm and the labour supply. It is not to be expected, therefore, that the graphical presentation of the history of dairy cattle herds in terms of the annual number of registrations would show such clearly marked changes with the success or otherwise of a herd as were demonstrated by Donald and Auerbach. Nevertheless it has seemed worthwhile to draw a number of histograms illustrating the growth and decline of herds of various durations. Some of these histograms are shown in Figs. 7 and 8.

The short-lived herds are of less interest than those of long duration. The latter include herds which apparently built up their numbers to the maximum in the first few years and then remained more or less stationary. Even these, however, varied greatly from year to year in the number of females registered as compared with pig herds. Fluctuations in the sex ratio no doubt caused much of this variation, and in Ayrshire herds, there was a period (1917-19) of/

of three years when no registrations took place, followed by a year or two of very large numbers of registrations of cattle born during those three years. The Ayrshire herds also show the way in which the Appendix stock was gradually replaced by fully pedigreed animals. Some Jersey herds behaved rather like pig herds in expanding rapidly but fairly regularly, while others remained fairly steady in numbers. Herds in both breeds often increased suddenly in numbers, probably as a result of building extra accommodation, or of acquiring another farm. Little evidence could be found that herds declined in size or number of registrations prior to ceasing altogether. They seem to 'die' suddenly at their full size. This again is not unexpected because unlike pigs which can be easily reduced, a dairy herd of single-purpose cows is usually the major enterprise on a farm and has to be kept going at its full strength even if pedigree breeding is not paying.

FIGURE 7.

Annual herdbook registrations of cows and heifers made by individual Ayrshire pedigree herds.

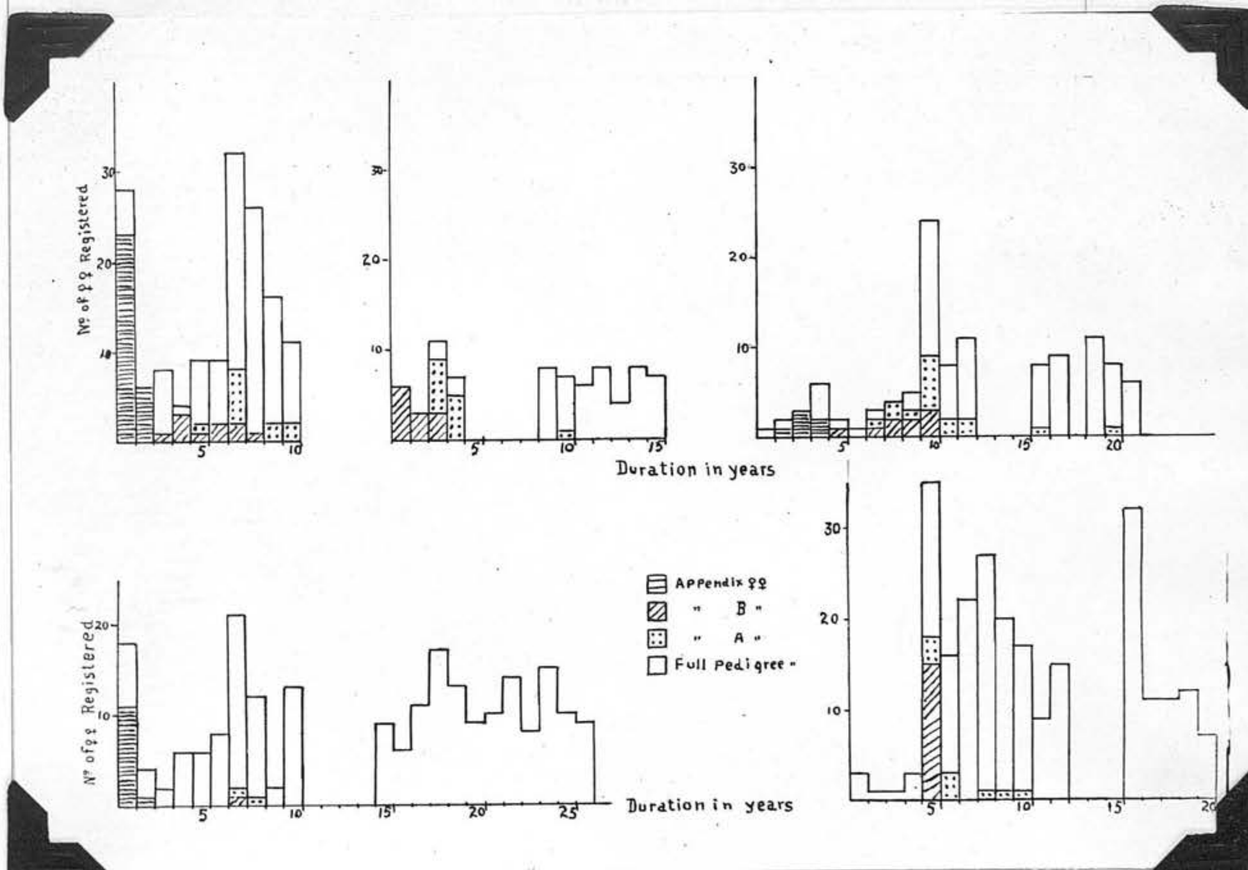


FIGURE 7 (contd.)

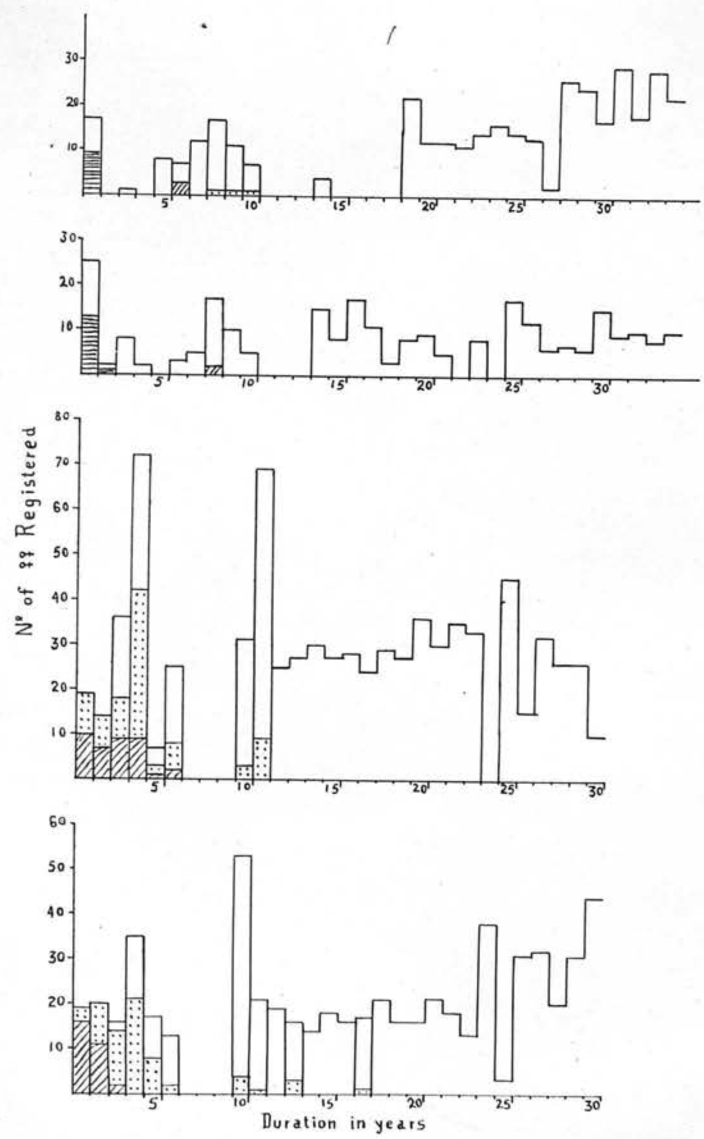
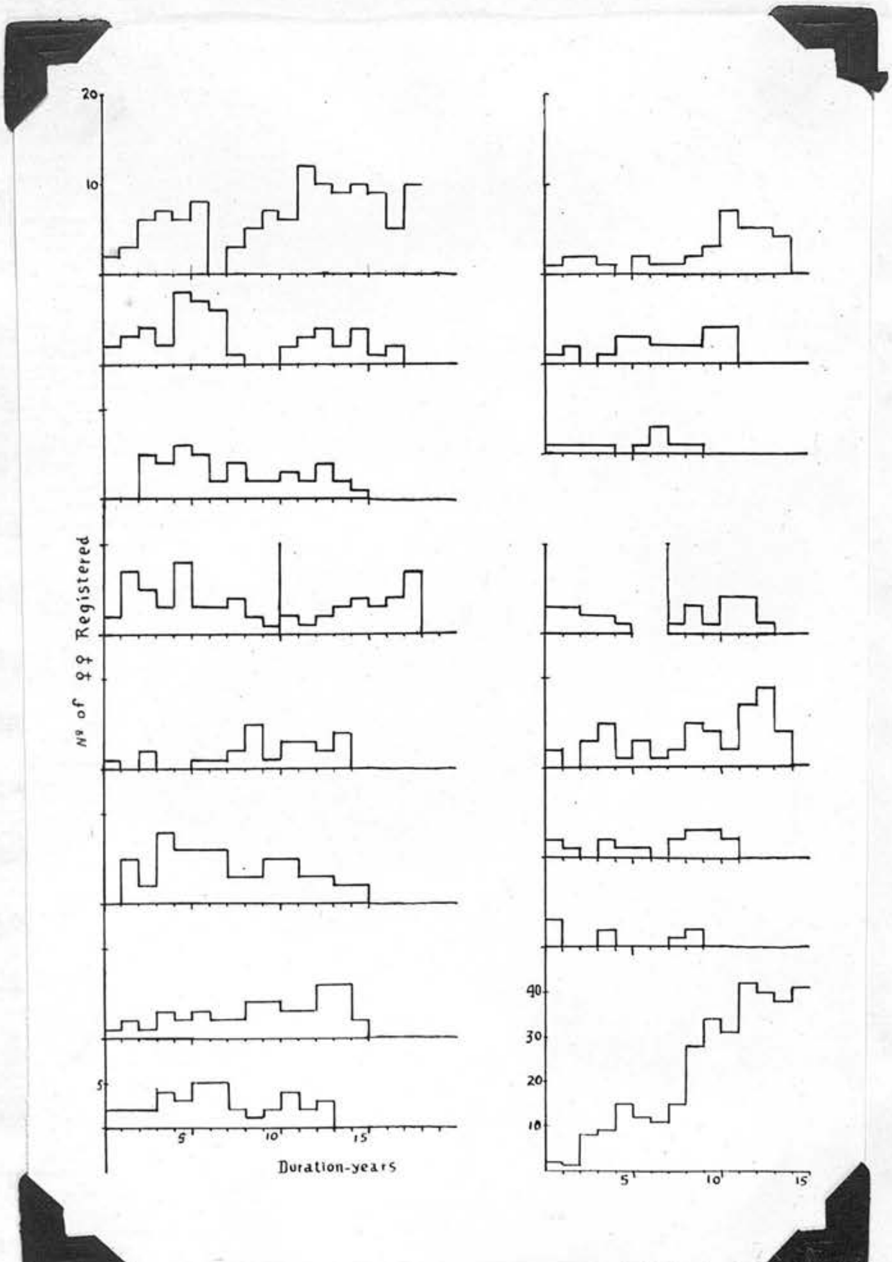


FIGURE 8.

Annual herdbook registrations of cows and heifers made by individual Jersey pedigree herds.



9. Discussion.

Subject, as it is, to the influence of economic conditions and propaganda, herd duration cannot be described accurately on the basis of limited samples drawn from a limited period of time. The intake of new herds, and their vitality, has been shown to vary greatly even from one year to the next, so that estimates of average duration, or of prospects for newly established herds, cannot be assumed to have any permanent or general validity. Nevertheless, such estimates as have already been made show clearly that a large proportion of pedigree dairy herds have a very short life - so short in fact that at any time a considerable number of breeders can have little or no significance from the point of view of breed improve::ment. In those breeds which do not comprise any substantial number of animals being graded up, these short-lived herds are usually founded on purchased pedigree stock. A few years' breeding is rarely sufficient to ensure either that the herd has been genetically improved or that when dispersed animals from it will enter other herds of good reputation in which they may play a part in creating future generations. Only those animals, especially bulls, which become the source of genes for future generations, have any permanent influence on the breed, hence most young herds and many older ones have little importance other than to provide an outlet for/

for sales of breeding stock, and a source of breeding stock for commercial herds or for other newly started herds.

It would be impossible, as breed associations are at present organized, to discriminate between herds of importance to the genetical future of the breed and those which are not. If this could be done it would obviously enable the effort of careful selection to be concentrated where it would be effective. Such an arrangement would be essentially the same as Hagedoorn's nucleus breeding scheme (1939). The practical difficulties of classifying herds in this way are very great since new herds cannot be graded according to their probable duration or to their permanent influence on the breed. The waste of effort in breeding is so extensive, however, and the lifetime of breeders so short in relation to the task they undertake, that some measures might be designed to minimize the difficulties. Firstly, encouragement could be given (in practical ways) for young breeders with a long expectation of life to start pedigree breeding early in life. Secondly, these young breeders and others could be required or encouraged to use their herds, at least for the first few generations, as testing grounds for young bulls bred in genetically influential herds. Plans would, of course, have to be made at the same time to ensure that milk recording was carried out and the data so obtained analysed and correlated/

correlated by some central agency. Either the breed society or the original breeder would have to have some control for the duration of this testing period over the disposal of stock, for without it, the success in locating valuable animals or strains might lead only to temporary exploitation without permanent effects. The prospects for any success of such a scheme may be much better now than formerly. Increasing numbers of young farmers receive the benefits of agricultural training. The limitations of pedigree breeding in its present form are becoming better realized, and the technique of artificial insemination has provided an opportunity for devising and carrying out breeding plans on a large scale.

10. Summary.

1. Of 328 Ayrshire herds founded in 1905-12, 32% lasted for more than 20 years and 25% for more than 25 years. In a sub-group established in 1905-8, 19% lasted only 1-5 years, and in another sub-group established in 1909-12, 28% lasted only 1-5 years. A rough estimate of the time spent in breeding Appendix females prior to first herdbook entry came to 5-6 years.

2. These 328 Ayrshire herds included 224 kept throughout by one breeder on one farm. The remainder were transferred at some time to other breeders (usually a member of the same family) or other farms. The average duration of pedigree breeding in the 224 herds with one breeder (counting herds still in existence in 1939 as defunct then) was found to be 13 years in the first group and 11.7 years in the second. To these estimates should be added about 5.5 years for pre-herdbook breeding, and a period for the further life of herds still existing in 1939.

3. The duration of breeding by individual breeders was slightly less than herd duration, about 64% of breeders did not last more than 15 years or about 3 generations of cows.

4. The duration of 665 pedigree Jersey herds established@

4. (contd.)

established since 1924 has been worked out. It is estimated that 17% and 10% disappear in the first and second years' of life, and that about 24% last more than 15 years. In the first 5 years, 50% of the herds became defunct.

5. Ayrshire herds making herdbook entries in the 1940 Volume numbered 758, and their average duration up to 1940 was 13.4 years. Owing to the growth of the breed, the average age of existing herds will be less than their total duration or expectation of life. 74% of these herds were of not more than 20 years' duration. Evidence is given to show the extent to which herds of short duration register fewer males and females than herds of long duration. While old herds contribute more bulls than expected from their numbers, nevertheless many bulls are reared by new breeders, and many old breeders rear no bulls in a given year.

6. In the Jersey breed, which has not shown the expansion found in the Ayrshire breed, there was also a preponderance of young herds in a sample of 345 herds registering females in 1941, about 75% of them being of 1-15 years' duration, and 39% of 1-5 years' duration. The distributions of duration for existing Ayrshire and Jersey herds were/

6. (contd.)

were found to be similar, but Ayrshire herds were much larger and reared relatively more bulls. Even in the oldest herds, the ratio of bulls : heifers registered does not become closer than 1:8 in Jersey and 1:3.4 in Ayrshire herds.

7. The history of the growth of typical herds is shown graphically.

8. The disadvantages of short herd duration are discussed and suggestions made for minimizing them.

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